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S 2D

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Abstract

I . T P , . I - S . (2003), . T DNS . T 2D , - .

Keywords: C ; D ; C ; N ; V -

1. Introduction

C , P [18] [13,1] . S , [21,2,38,27] [11,8,37,27,14]. V [11]. B - [5,10], [2,36]. H , [27] .

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F ... u' ... $u(x_j)$, $j = 1 \ldots N$,

$$[A]\{u'\} = [B]\{u\}. \quad (1)$$

W ... (A ...) ...

$$\{u'\} = \frac{1}{h}[C]\{u\}, \quad (2)$$

h ... . I ... A ... B ... C ... . T ... . C ... A ... B ... . M ... -H ... A ... B ... (-H). I ... B ... [1,21,11] ... B ... [38,2]. T ... A ... B ... . E ... . T ...

I ... ([21,37]) ... . T ... GKS L ... [10], ...) ... . F IBVP ... H ... . U ... [5,2,27]. T ... [5,2] GKS ... . T ... [27], F L ... (DRP) ... . S ... [29 31] ...

U ... [27] ... . I ... . I ... (F . 2 [27]). I ... *inflow* ... *outflow* ... . I ... ([2,38]) ... *inflow*. T ... . N ... *outflow* ... . A ... ([23,32]). B ... *outflow* .

H ... *inflow* ... . I ... DNS, ... *inflow*. I ... DNS ... . I [27], ... (...) ...

inflow, *outflow*. I
[27] (*OUCS*3-) . T
- [27,28,33]
outflow
R .
F ,
/ . T -
2D - - -
. O
.
C
, . T
. T ( )
N S O S
T -S (TS). T , 2D
TS . T R
R . I
- 3D .
T ([7]) R (*Re*)
5772 . H , -
R 1000 ([45,46])
- . A -
[20], R
$Re_G = 1000$. A M S [24] $Re_G = 2900$. I
, - . I
, - - - -
([39 44]). I -
- *destructive interference of the various modes can decrease as time evolves, leading to the possibility for transient energy growth which is sometimes quite large* [43] [40], 200. A [42],
. I
- , H . [47]
.

P - -
. I [22],
[28], /
. I [33],
.
I [6],
([7, . 452]), 40 160.
I , *inlet pipe generated quite strong eddies at the upstream end of the channel*. T
Re ( ),
: ( ) $Re < 200$, ; ( ) $200 < Re < 2000$,
-
. B , - . .
- ( ) ( ) $Re > 2000$
- , *corresponding to truly turbulent flow* .
T , , , *Re* 2000. T
- .

P . T , W - - . M DNS R . I [4], , [12] . T [16]. , A , *permanent patches of unsteady behavior, resembling the turbulent 'puffs' observed in circular pipes, are found at low Reynolds numbers*

I . E [16] , - . O T , ( )/ ( ) . I (3D) , . P [17] , . H , F . W , - DRP [27]. B *chaotic* [16]. F , [35] - - N S $Re = 5600$ - [19]. F , $(64 \times 64 \times 32)$. C .

I , [25,3] DRP [29]. I , - - N S ([35]). F N S , [25,16] [29] - A B - . T DNS . F *chaotic* ,

T - A . T . I , T . I , - 1D . I S 3, - R . T .

2. High accuracy symmetrized compact scheme

I ... :

$$b_{j-1}u'_{j-1} + b_j u'_j + b_{j+1}u'_{j+1} = \frac{1}{h}\sum_{k=-2}^{2} a_{j+k}u_{j+k}. \quad (3)$$

F ... $OUCS3$, [27], ... : $b_{j\pm1} = 0.3793894912 \pm \frac{\eta}{60}$; $b_j = 1$; $a_{j\pm1} = \pm 0.7877868 + \frac{\eta}{30}$; $a_{j\pm2} = \pm 0.0458012 + \frac{\eta}{300}$ ... $a_j = \frac{-11\eta}{150}$, ... $\eta = -2$ ... $OUCS3$ ... . T ... . W ... , - ... E . (3) ... . T ... $OUCS3$ ... - ... $j = 1$ ... $j = 2$, ... [27]:

$$u'_1 = \frac{1}{2h}(-3u_1 + 4u_2 - u_3), \quad (4)$$

$$u'_2 = \frac{1}{h}\left[\left(\frac{2\gamma_2}{3} - \frac{1}{3}\right)u_1 - \left(\frac{8\gamma_2}{3} + \frac{1}{2}\right)u_2 + (4\gamma_2 + 1)u_3 - \left(\frac{8\gamma_2}{3} + \frac{1}{6}\right)u_4 + \frac{2\gamma_2}{3}u_5\right], \quad (5)$$

... $\gamma_2 = -0.025$ ... [27]. S ... , ... - ... $j = N$ ... $j = (N-1)$ ... $\gamma_{N-1} = 0.09$. N ... - ... . W ... E . (3)–(5), ... A, B ... C ... E . (1) ... (2) ... . T ... , ... E . (3) ... $j = 3$ ... $N-2$ ... A ... , ... B ... - ... . W ... [26,27] ... .

T ... , ... - L ... :

$$u(x_j) = \int_{k}^{k} U(k) \; {}^{kx_j} \, k, \quad (6)$$

... k ... k ... U ... - ... L ... F ... . I ... , $k = -k = \pi$, ... , ... O ... $k = 0$ ... 2π- ... . T x_j ... F ... $u'(x_j) = \int kU(k) \; {}^{kx_j} \, k$ ...

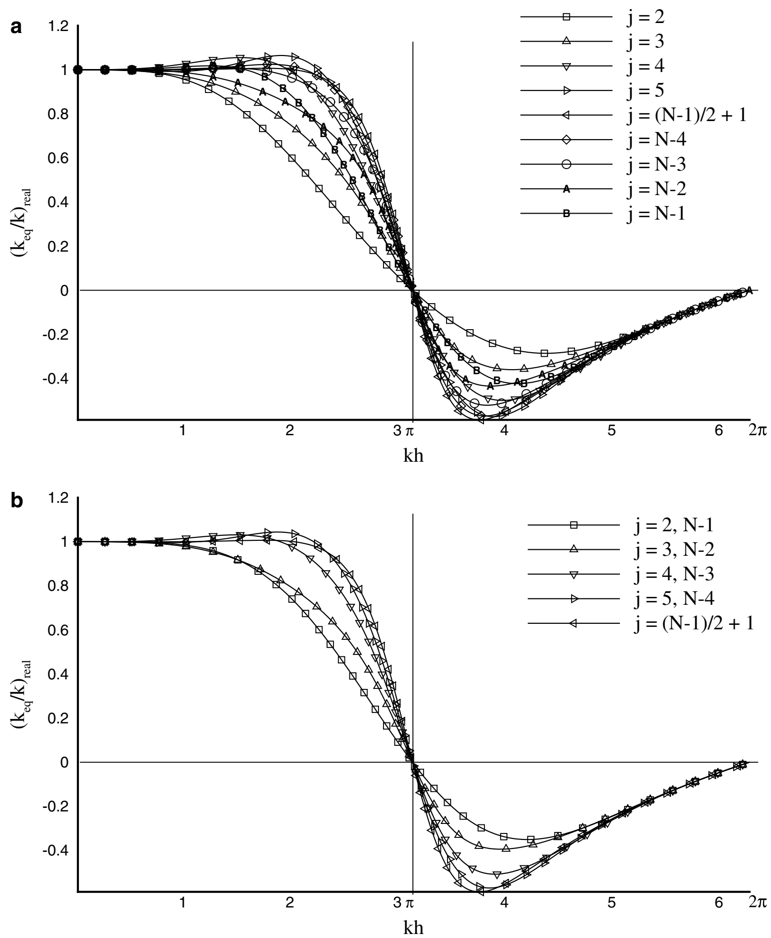
$$u'(x_j) = \int k \, U(k) \; {}^{kx_j} \, k.$$

U ... E . (6) ... E . (2) ... , ...

$$k \, (x_j) = \sum_{l=1}^{N} C_{lj} \; {}^{k(x_l - x_j)}. \quad (7)$$

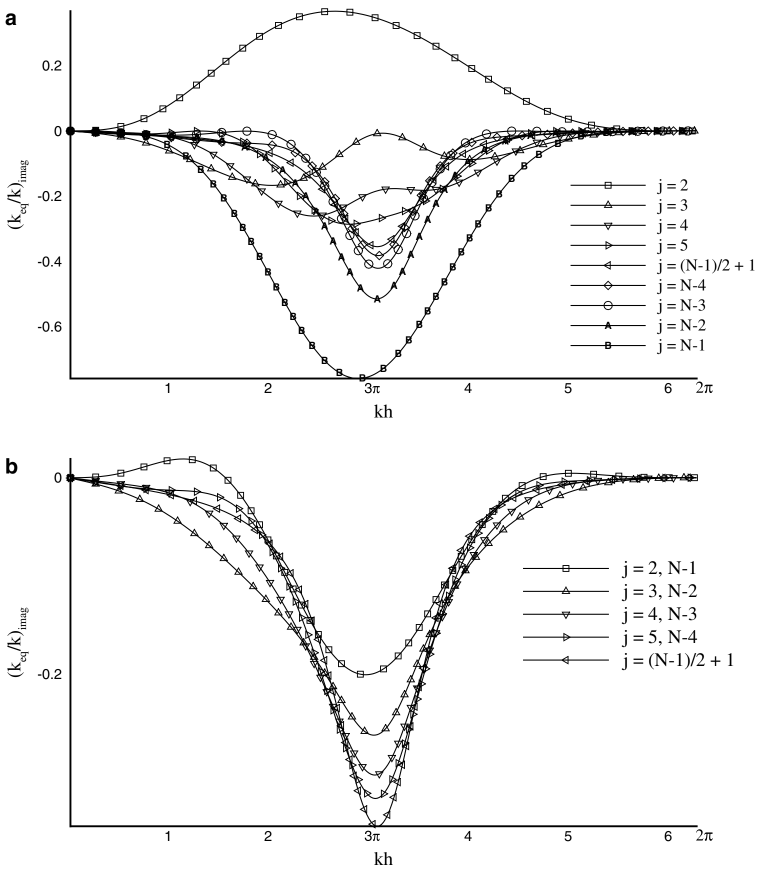
T ... , j ... C ... j ... k ... E . (7). T ... k/k ... [21,27] ... kh ... 0 ... π.

I F . 1( ) ... 2( ), ... k/k ... kh ... 0 ... 2π ... 31 ... . O ...



F . 1. R (k/k) ( ) OUCS3 ( ) S-OUCS3, $N = 31$.

k/k . F F . 1( ),
$OUCS3$. T
- (16) -
. F . 2( ) $OUCS3$
. T $[k/k]$,
(30)
A E . (7) C
. T C
E . (3) -
E . (4) (5). T - η E . (3). T ,
$\eta = 0$ E . (3). F C
C E . (2)
. F , 2
30 C- . T k/k F . 1( )
2( ). D ,
F . 1( ) ( ) 2( ) ( ). F F . 1,
- , F . 2,
$j = 2$ T



F . 2. I (k_{eq}/k) ( ) - OUCS3 ( ) S-OUCS3, $N = 31$.

. W *S-OUCS3*

I , DRP . T ,

$$\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} = 0, \quad c > 0. \tag{8}$$

T . E - - , . E. (8) - c. T - c. H , DRP . D , . I [27,31], DRP [34]. F , . T E. (8).

C ... Eq. (8) ... :

$$u_m^0 = u(x_m, t = 0) = \int A_0(k) \quad {}^{kx_m} \quad k. \tag{9}$$

T ... Eq. (8) ...

$$u \quad (x, t) = \int A_0(k) \quad {}^{k(x-ct)} \quad k. \tag{10}$$

T ... $x = x_m$ ... $t = t^n$ ... $u_m^n = \int \hat{U}(k, t^n) \quad {}^{kx_m} \quad k$, ... $G(k) = \frac{\hat{U}(k,t^{n+1})}{\hat{U}(k,t^n)}$. T ... N ... O ... Eq. (9) ... Eq. (8) ... [29]

$$u_m^n = u(x_m, t^n) = \int A_0(k)(G_r^2 + G_i^2)^{n/2} \quad {}^{k(x_m - n\beta)} \quad k, \tag{11}$$

... $G(k) = G_r(k) + \quad G_i(k)$ ... $\beta = -G_i/G_r$. C ... Eq. (10) ... (11), ... β ... c ...

F ... Eq. (11), ... $k(x_m - n\beta) = k(x_m - c_N t^n)$, ... c_N [29,31]

$$\frac{\hat{c}_N(k)}{c} = \frac{\beta}{\omega \Delta t}, \tag{12}$$

... $\omega_N = \hat{c}_N k$ ... $\omega = ck$. T ... [29,31]

$$\frac{V_{gN}(k)}{c} = \frac{1}{N_c h} \frac{\beta}{k}, \tag{13}$$

... $N_c = c\Delta t/h$ ... CFL ...

F ... DNS, ... $(|G| = 1)$ ... $(\hat{c}_N(k) = c)$. T ... $G_r^2 = \quad {}^2(khN_c)$ ... . N ... $k \quad /k$, $G(k)$ ... $V_{gN}(k)$ ... F ... Eq. (8), ... (CD_2) ... E ... [29]

$$G(kh, N_c) = [1 + N_c^2 \quad {}^2 kh]^{1/2} \quad {}^{-\beta},$$

... $\beta = -N \quad (kh)$. V ...

F ... I ... j ... Eq. (7),

$$\frac{\partial u_j}{\partial x} = \frac{1}{h} \sum_{l=1}^{N} C_{lj} \quad {}^{k(x_l - x_j)} u_j. \tag{14}$$

U ... Eq. (8),

$$\frac{\partial u_j}{\partial t} + \frac{c u_j}{h} \sum C_{lj} [\quad k(x_l - x_j) + \quad k(x_l - x_j)] = 0. \tag{15}$$

T ... j ... $G_j(k)$, ... F ... E ... j ...

$$G_j(kh, N_c) = G_{jr} + \; G_{ji} = 1 - N_c \sum_{l=1}^{N} C_{lj} \big[(\quad k(x_l - x_j) + \quad k(x_l - \text{[redacted]} \tag{16}$$

β_j [redacted] $(\beta_j) = -G_{ji}/G_{jr}$. T , -

j ,

β β_j E . (12) (13). B [redacted] [31], DRP

- R K (RK_4) ,

. I $L(u) = -c \frac{\partial u}{\partial x}$, RK_4 [redacted]

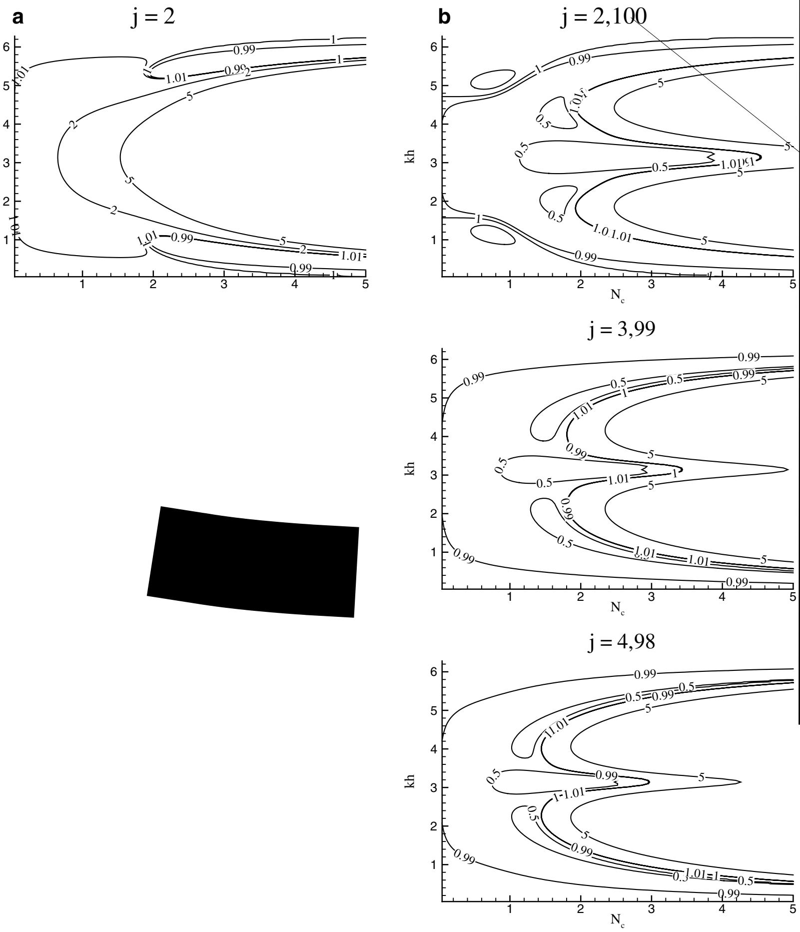
$$\text{S -1}: \quad u^{(1)} = u^{(n)} + \frac{\Delta t}{2} L[u^{(n)}],$$

$$\text{S -2}: \quad u^{(2)} = u^{(n)} + \frac{\Delta t}{2} L[u^{(1)}],$$

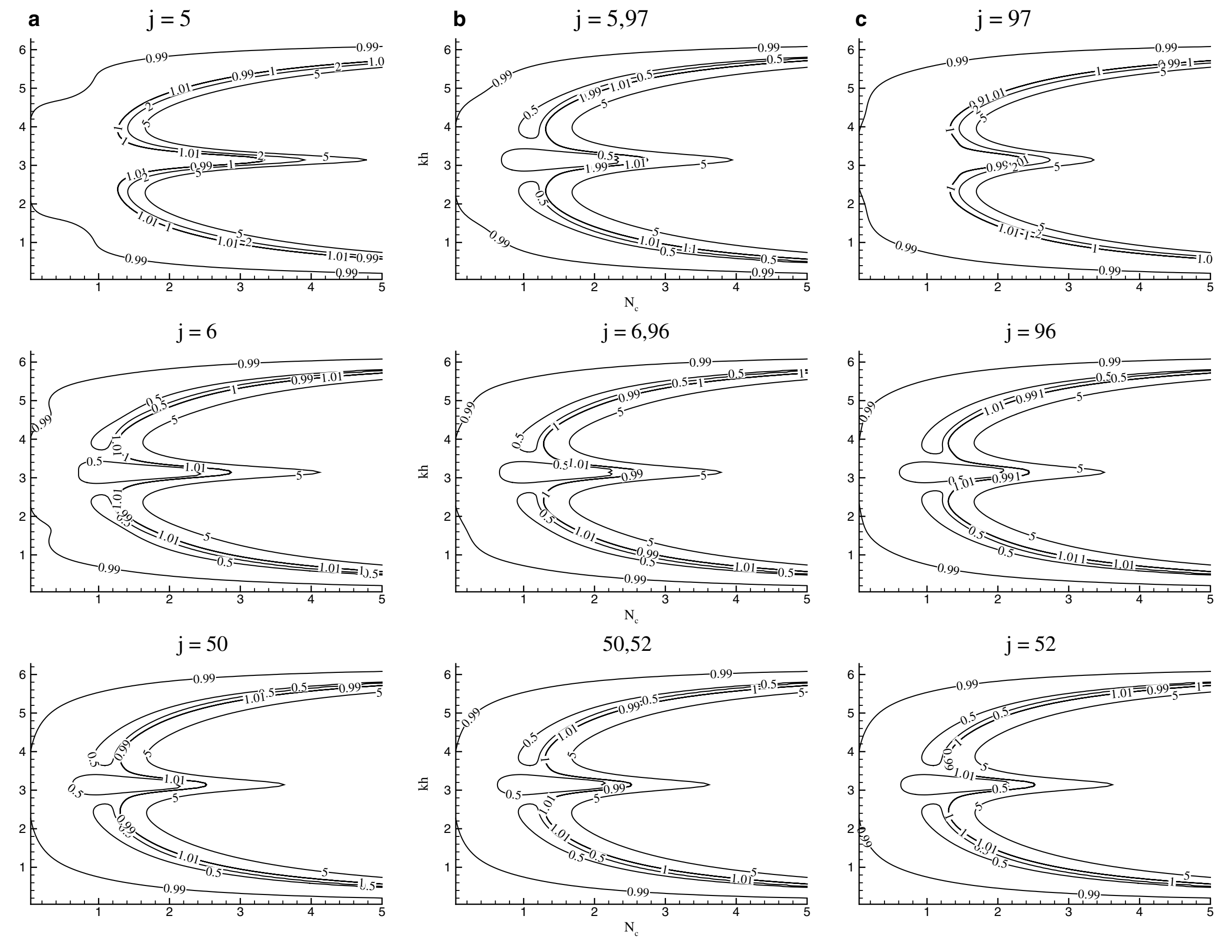
$$\text{S -3}: \quad u^{(3)} = u^{(n)} + \Delta t L[u^{(2)}],$$

$$\text{S -4}: \quad u^{(n+1)} = u^{(n)} + \frac{\Delta t}{6} \left\{ L[u^{(n)}] + 2L[u^{(1)}] + 2L[u^{(2)}] + L[u^{(3)}] \right\}.$$

T RK_4 , j [redacted] [26]



[redacted]



F . 3 (*continued*)

$$G_j(kh, N_c) = 1 - A_j + \frac{A_j^2}{2} - \frac{A_j^3}{6} + \frac{A_j^4}{24}, \tag{17}$$

$$A_j = N_c \sum_{l=1}^{N} C_{lj} \quad {}^{k(x_l - x_j)}. \tag{18}$$

U E . (17) (18),
kh N_c RK$_4$. I C
j $(N-j+1)$ C N
. S . I F . 3, G_j
$N = 101$. O F . 3, -
j $(N-j+1)$
*OUCS*3 I F . 3, *S-OUCS*3
. R $j = 2$ $j = 100$ -
*OUCS*3 . I , *S-OUCS*3
j S
- , G
$j \geqslant 6$

4,

S-O

kh

10^−5. A ,

)8. I

E (8)

Δ

F ... S-OUCS3 ( ) S-OUCS3

I E . (21) λ_1 λ_2

$$\lambda_1 = F \ {}^{\eta}, \tag{22}$$

$$\lambda_2 = H \ {}^{\Gamma}, \tag{23}$$

$$u_m^n = \int M(k)[F]^n \ {}^{(kx_m+n\eta)} k + \int N(k)[H]^n \ {}^{(kx_m+n\Gamma)} k, \tag{24}$$

$M(k)$ $N(k)$. A [31] . T . H , E . (19) . H ,

I . $\frac{\partial^2 u}{\partial x^2}$ E . (19) [21]. W *S-OUCS*3 [21] E . (19). T [21] ,

$$j = 1: \quad u_1'' + 11u_2'' = (13u_1 - 27u_2 + 15u_3 - u_4)/h^2, \tag{25}$$

$$j = 2: \quad u_1'' + 10u_2'' + u_3'' = 12(u_3 - 2u_2 + u_1)/h^2, \tag{26}$$

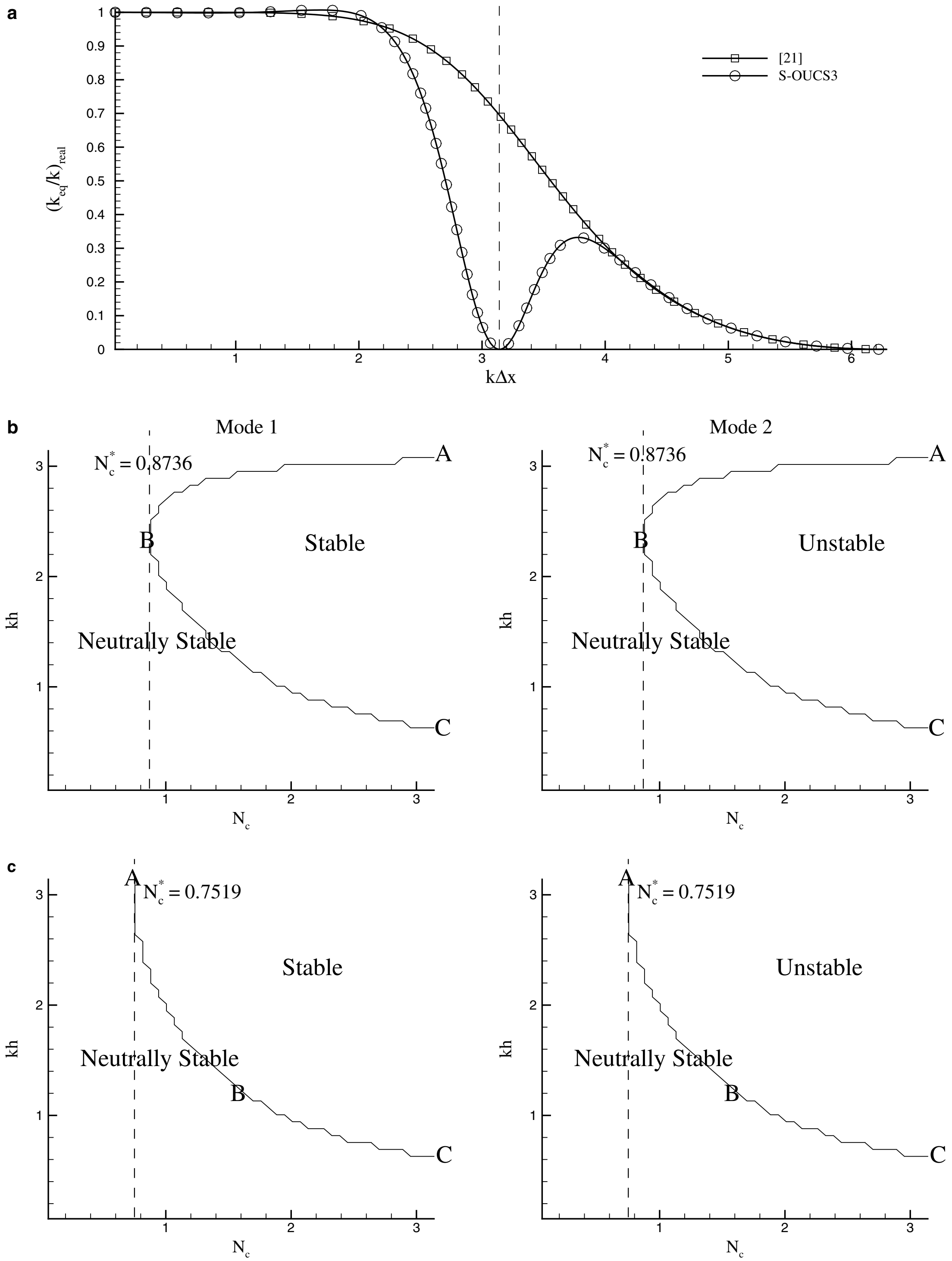
$$3 \leqslant j \leqslant N-2: \quad \alpha u_{j-1}'' + u_j'' + \alpha u_{j+1}'' = \frac{b}{4h^2}(u_{j-2} + 2u_j + u_{j+2}) + \frac{a}{h^2}(u_{j-1} - 2u_j + u_{j+1}). \tag{27}$$

O $j = N$ $N - 1$ E . (25) (26), . I [21], $\alpha = 2/11$; $a = 12/11$ $b = 3/11$ E . (27). T $\frac{\partial^2 u}{\partial x^2}$ E . (6), $u'' = -\int k^2 U(k) \ {}^{kx} k$ $\frac{k_{eq}^2}{k^2}$. M [21] *S-OUCS*3 . T F . 5( ); ($\frac{k_{eq}^2}{k^2}$) kh 0 2π . I , *S-OUCS*3 k_{eq}^2 $kh = \pi$, [21] 0.7 . T *S-OUCS*3 .

A P_j^2 E . (21) . I F . 5( ) ( ), E . (25) (27) *S-OUCS*3 (kh N_C)- . T . F ABC , - ABC . N ABC, . I CFL (N_c^*) kh . F *S-OUCS*3 0.8736 $N_c^* = 0.7519$. T , , *S-OUCS*3 . T kh 1.8 (F . 4) [21] .

W E . (19) -

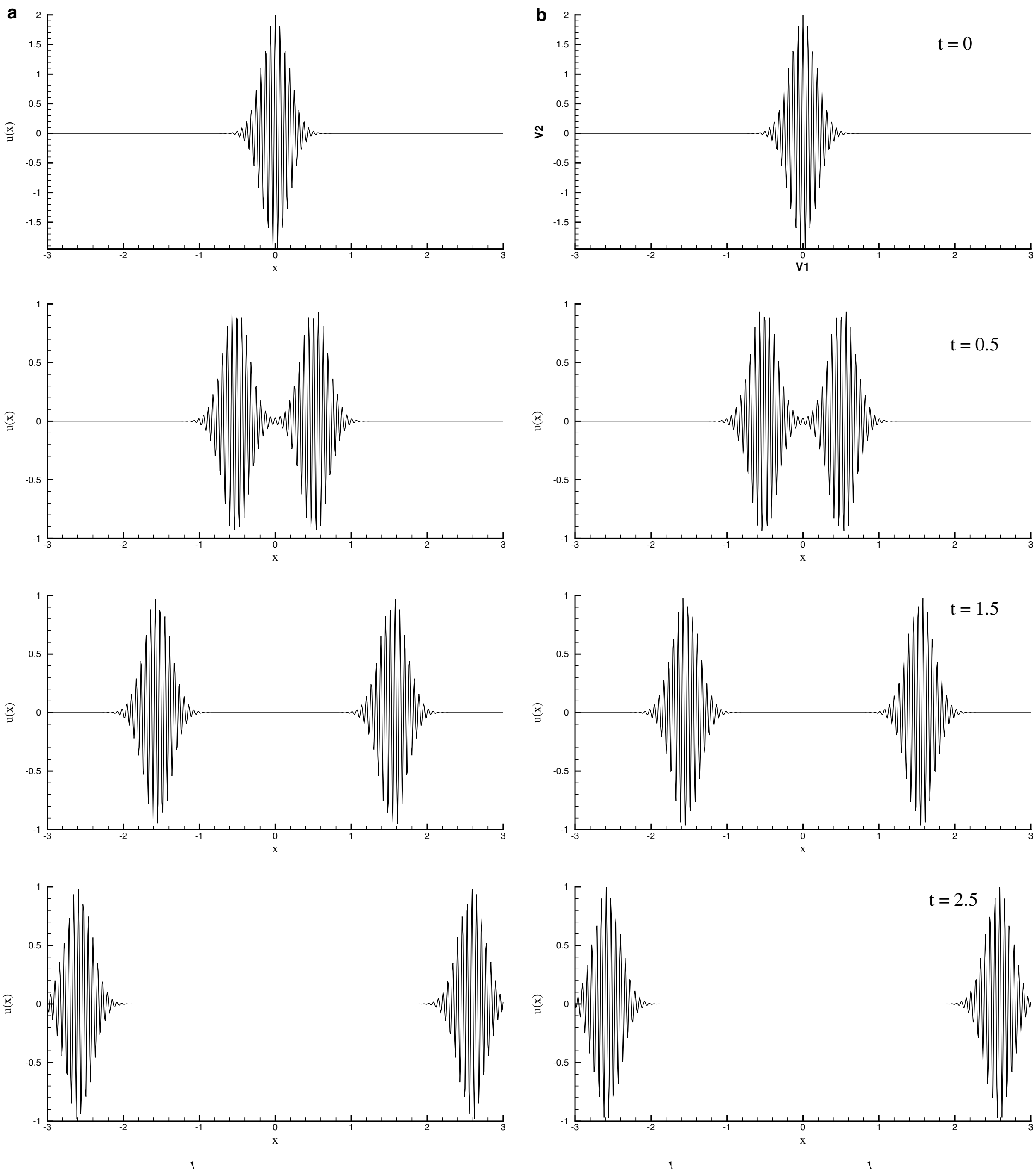
$$u_0(x) = 2 \ {}^{-16x^2} \ {}^{k_0 x}. \tag{28}$$



F . 5. N S-OUCS3 [21], : ( ) $(k\ /k)$. A ($|G|$) ( ) S-OUCS3 ( ) [21]. A .

T $k_0h = 1$. F k_0h, F . 4 5. T $c = 1$. T

$-3 \leqslant x \leqslant 3$ F . 6 . B (3) (27) (4), (5) (25), (26) . H , F . 6 . T *S-OUCS*3 . I 2D .



F . 6. C E . (19) ( ) S-OUCS3 ( ) [21], .

4. Transitional flow in a channel

W *S-OUCS*3 *OUCS*3 - N S , (ψ) (ω) (SFE) (VTE):

$$\nabla^2\psi = -\omega \tag{29}$$

$$\frac{\partial\vec{\omega}}{\partial t} + (\vec{V}\cdot\nabla)\vec{\omega} = \frac{1}{Re}\nabla^2\vec{\omega}. \tag{30}$$

T - , . A . T - $(\xi\ \eta)$

$$\frac{\partial}{\partial\xi}\left[\frac{h_2}{h_1}\frac{\partial\psi}{\partial\xi}\right] + \frac{\partial}{\partial\eta}\left[\frac{h_1}{h_2}\frac{\partial\psi}{\partial\eta}\right] = -h_1h_2\omega \tag{31}$$

$$h_1h_2\frac{\partial\omega}{\partial t} + h_2u\frac{\partial\omega}{\partial\xi} + h_1v\frac{\partial\omega}{\partial\eta} = \frac{1}{Re}\left[\frac{\partial}{\partial\xi}\left(\frac{h_2}{h_1}\frac{\partial\omega}{\partial\xi}\right) + \frac{\partial}{\partial\eta}\left(\frac{h_1}{h_2}\frac{\partial\omega}{\partial\eta}\right)\right], \tag{32}$$

h_1 h_2

$$h_1^2 = \left(\frac{\partial x}{\partial\xi}\right)^2 + \left(\frac{\partial y}{\partial\xi}\right)^2$$

$$h_2^2 = \left(\frac{\partial x}{\partial\eta}\right)^2 + \left(\frac{\partial y}{\partial\eta}\right)^2.$$

I , F

$$x(\xi) = L\left[1 - \frac{[\beta_1(1-\xi)]}{[\beta_1]}\right] \tag{33}$$

$0 \leqslant \xi \leqslant 1$ $\beta_1 = 1.55$. T [4] $h_1 = x_\xi$. T , $f = 1/h_1$,

$$f = \frac{[\beta_1]}{4\beta_1 L}\left[\ ^{2\beta_1(1-\xi)} + \ ^{-2\beta_1(1-\xi)} + 2\right].$$

T - L f

$$\hat{F}(k) = \frac{(\beta_1)}{2\beta_1 L}\left[\delta(k) + \frac{1}{2}\delta(k-2\ \beta_1)[\quad 2\beta_1 - \quad 2\beta_1] + \frac{1}{2}\delta(k+2i\beta_1)[\quad 2\beta_1 + \quad 2\beta_1]\right].$$

T , $\hat{F}(k)$ - $k = 0$ $2\ \beta_1$. I , - . W - . T , *S-OUCS*3 - η . T x- *OUCS*3 ξ VTE.

T SFE, Eq. (31) [15], . T

T $\omega_b = -\frac{1}{h_2^2}\frac{\partial^2\psi}{\partial\eta^2}$ [26,33]. T VTE Eq. (32) *OUCS*3 *S-OUCS*3 . T R K S 1.

I , , SFE VTE, :

$$\frac{\partial u_x}{\partial t} + u_c \frac{\partial u_x}{\partial x} = 0 \quad (34)$$

$$\frac{\partial \omega}{\partial t} + u_c \frac{\partial \omega}{\partial x} = 0, \quad (35)$$

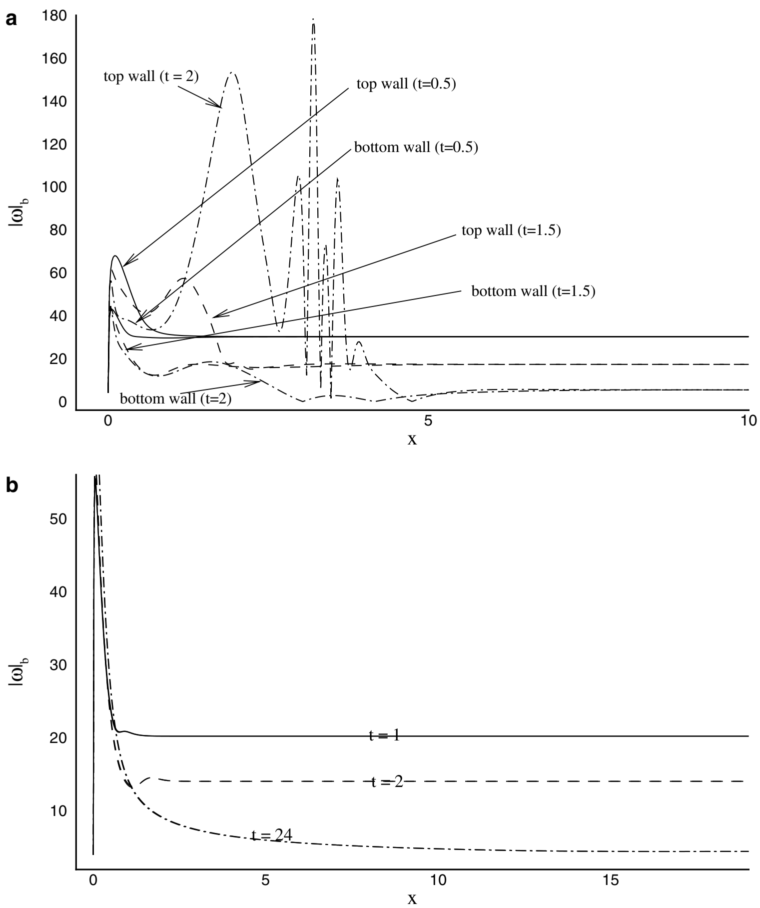
u_x C u_c - . T

4.1. Establishment of equilibrium flow

T , . O / . K [6,7], $Re = 800$ 2000, . W 1001 201 Eq. (33). T $30H$. T [3] (1024×128) T , [3].

I Fig. 7( ) ( ), $Re = 800$ *OUCS*3 *S-OUCS*3 , I , *OUCS*3 . I *S-OUCS*3 , *OUCS*3 , Fig. 7( ). O . P , *OUCS*3 $t \equiv 2$. T *OUCS*3 y- . I . B , DRP . T , [16,3].

I Fig. 8, $Re = 800$ *S-OUCS*3 y- . I Fig. 8( ), $t = 18$, 21 24.1. T $t = 24.1$. I Fig. 8( ), , . A , . T $t = 24.1$. T - *S* . I , , .



F . 7. V ( ) ( ) OUCS3 ( ) S-OUCS3, .

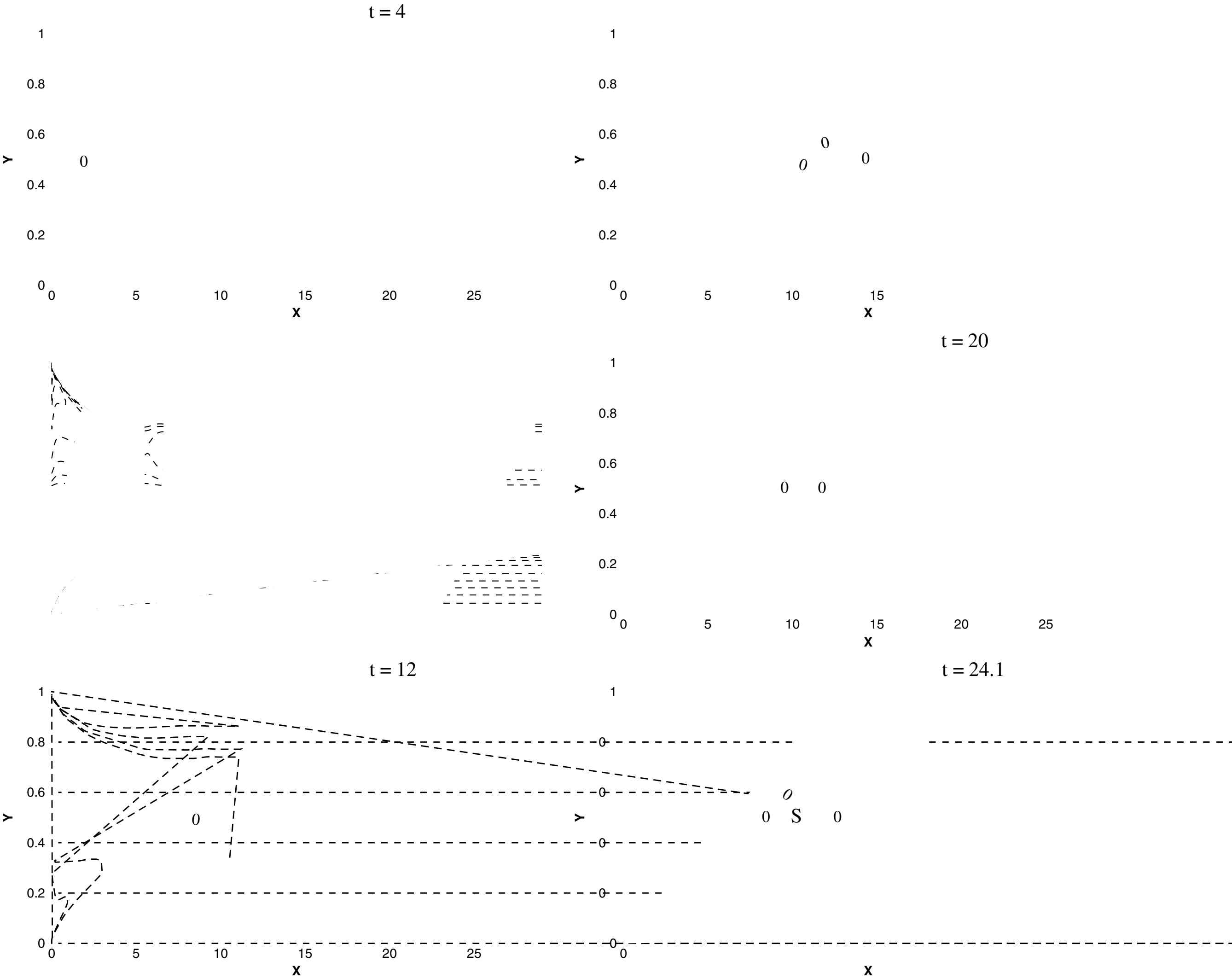
F . W $Re = 800$, $L = 20H$. T $t = 24$.

I F . 9, $Re = 2000$. F , $t = 59.8$.

4.2. Receptivity of channel flow to single viscous vortex

I - . F , . A , . T , - 2D . A , . W L -O (LOV) - N S [9]

$$\omega^*(r^*,t^*) = \frac{\Gamma_0^*}{4\pi\nu t^*} \quad \left(\frac{-(r^*)^2}{4\nu t^*}\right),$$


t = 4
t = 20
t = 12
t = 24.1
Y
X
0
0.2
0.4
0.6
0.8
1
5
10
15
20
25

F , Γ_0 τ - . S τ,
. A , E . (36),
τ, -
. F , LOV 10%
$x = 2H$ $t = 25$ $Re = 800$. W
, [6] $Re \leqslant 1000$.

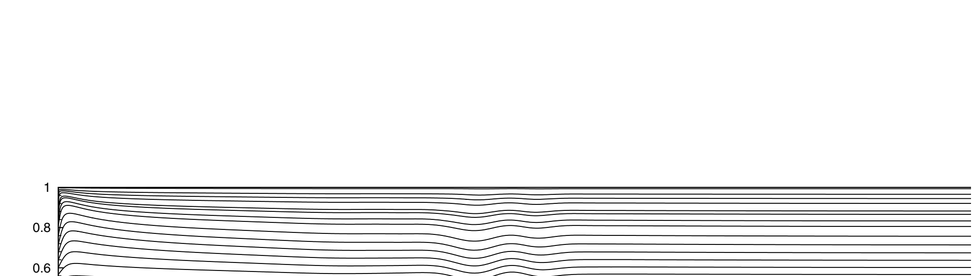
I F . 10, LOV. F
$t = 25$ -
. I [28], -
. F , -
- . I [28],
. W
, . I
. T
$t = 30$, . A ,
$t = 34$. F -
$Re \leqslant 1000$,
[6]. T -
[28] .

C F . 11, .
W ψ $t = 28$, -
. T LOV. I
, LOV. I
LOV . T , LOV
, E . (36). A $t = 31$, LOV
-
. B $t = 34$
. B $t = 41$, - -
. T
( ),
F . 11, LOV . C
F . 12. A - F . 11 ,
.

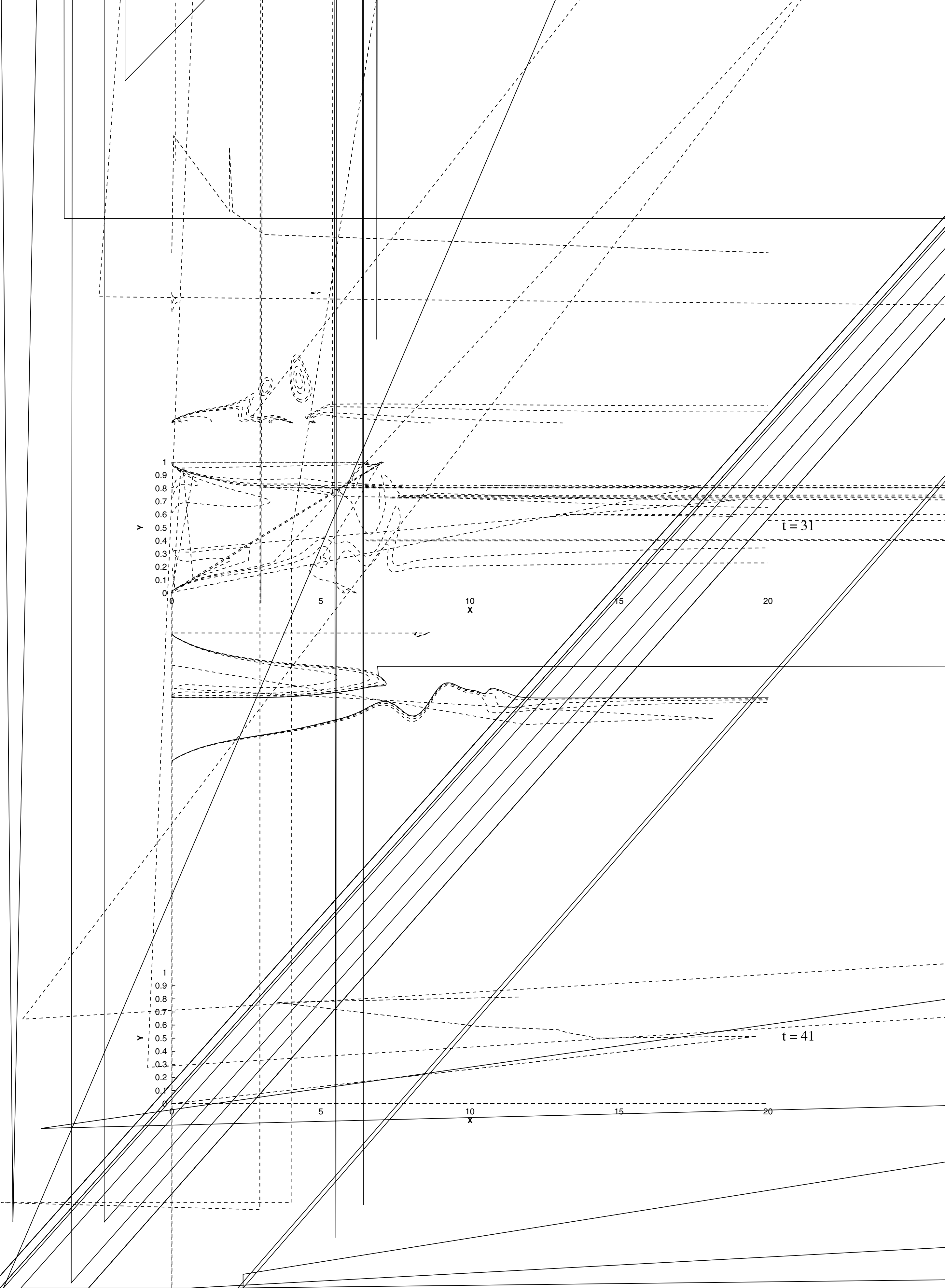
N , $Re = 2000$, [6] - .
H LOV $t = 20$ - 10-
1% , $Re = 800$. T
F . 13, . T , LOV
. T LOV - . T
$t = 35$ $t = 40$,
. A $t = 50$ - .
T 0.80 - .

4.3. Transition of a channel flow created by vortex street

I - , -
. H , . H ,
, F . 14. T R (H)

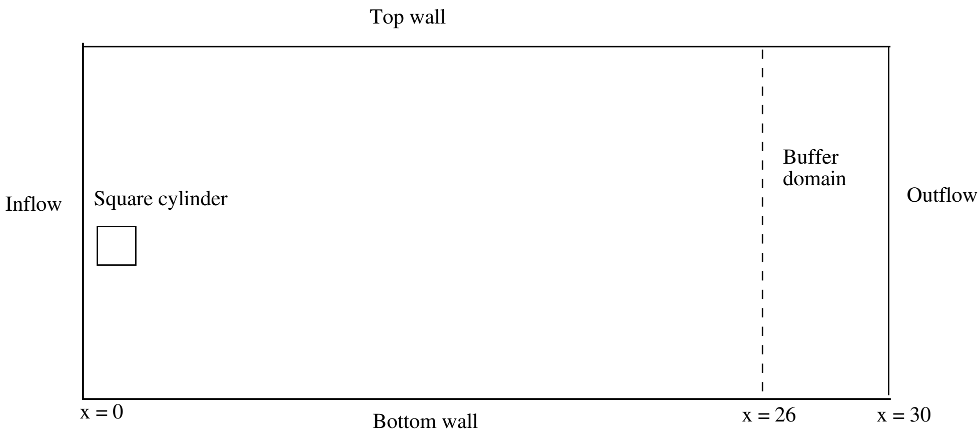


t = 41



t = 31
Y
X
t = 41
Y
X

F . 13. V [redacted]



F . 14. F . C , $a = 0.048H$.

2000 $0 \leqslant x \leqslant 30H$. A H . T $a = 0.048H$, R 96. A $t = 0$, . F , ([23,32]) . H , $26 \leqslant x \leqslant 30$ [23,32].

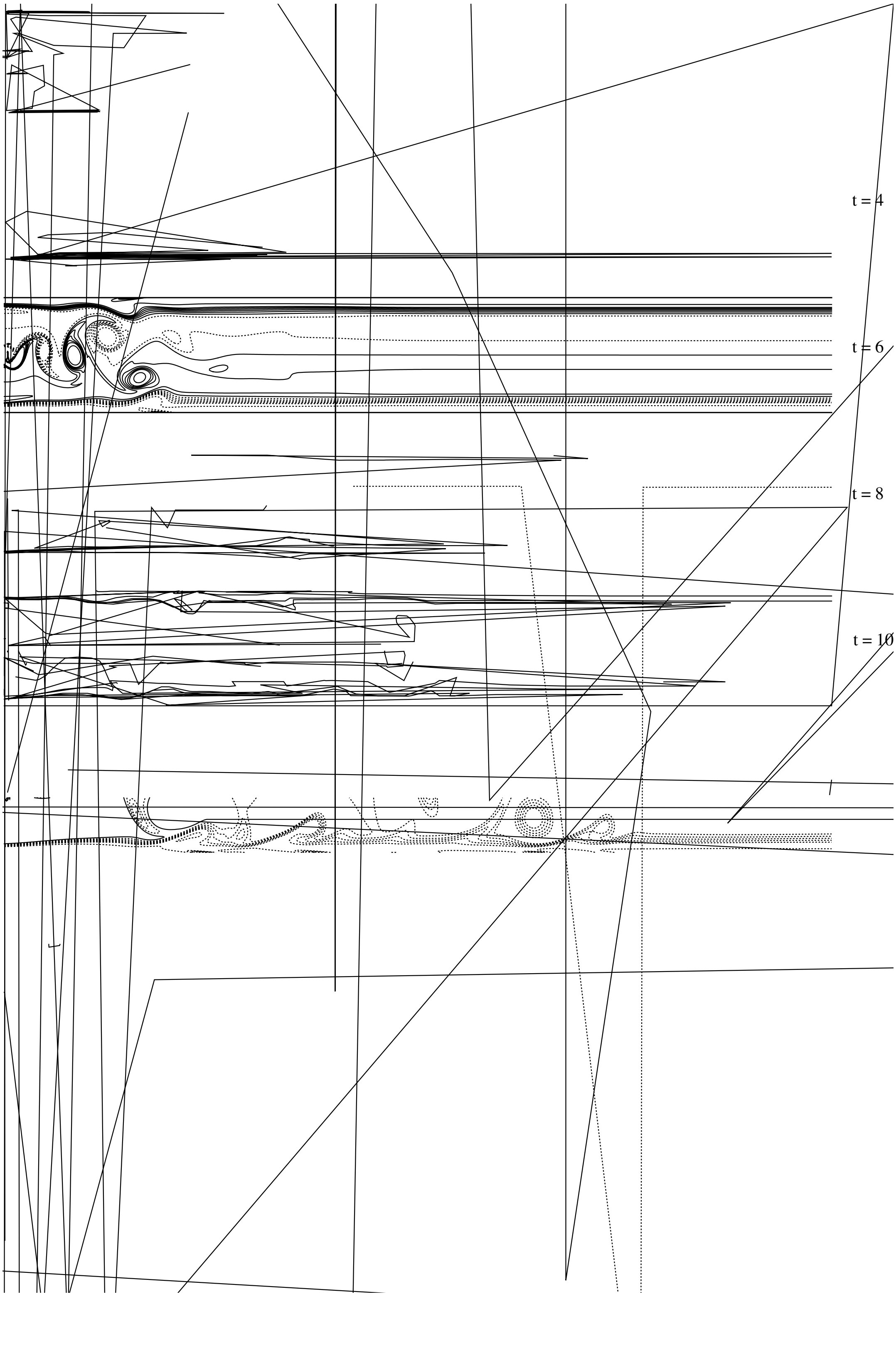
I [48], - - . F . 1( ) . T .

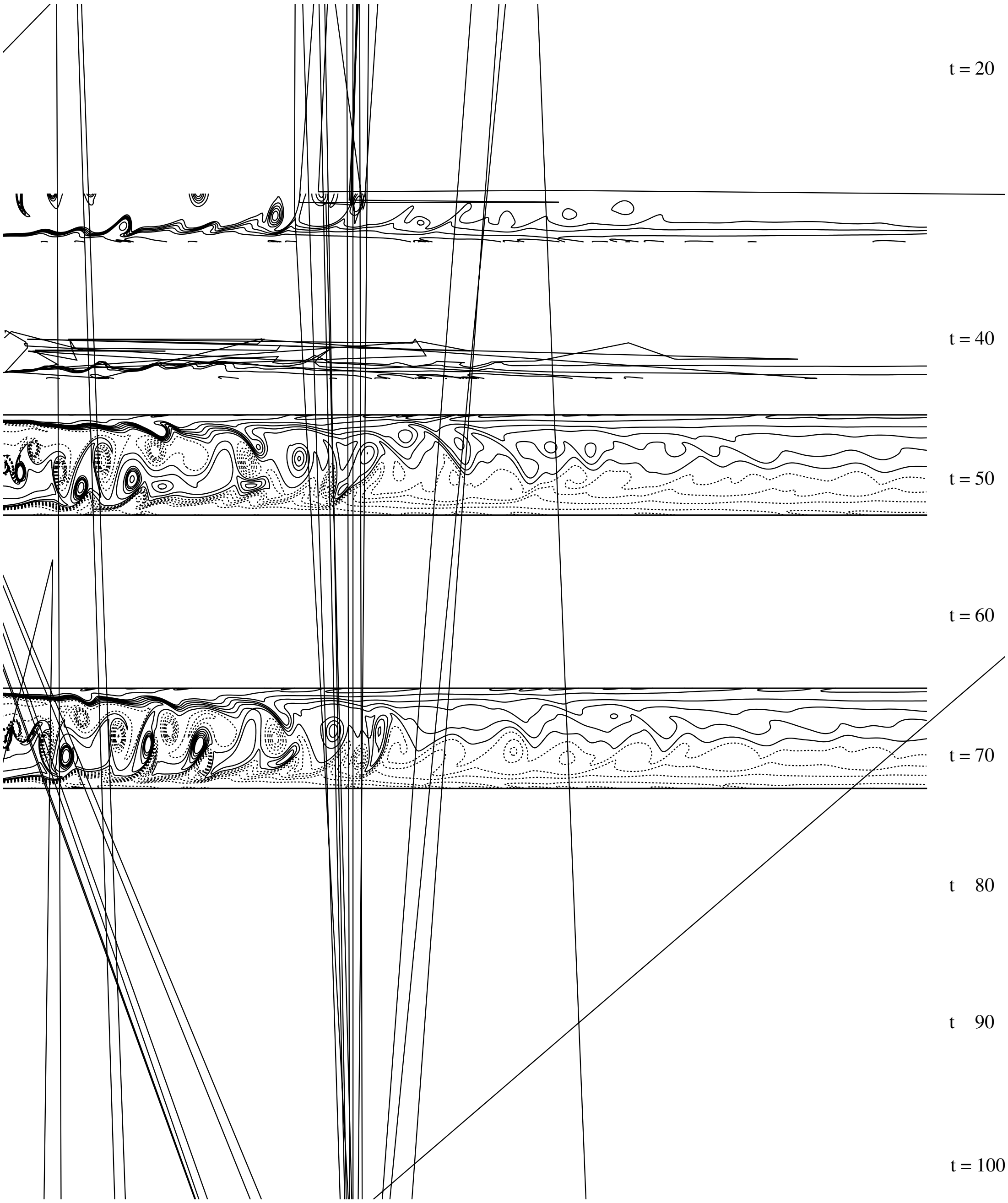
I F . 15( ) $x \leqslant 10$. A $t = 2$, . A A , . T $t = 6$ T . T - . I , . T , - , - - .

I F . 15( ), $1 \leqslant x \leqslant 20$ - . I , - . I . H , - .

5. Summary

I . T P , . I , -


t = 4
t = 6
t = 8
t = 10



F . 15( ). V $Re = 2000$, . N .

DNS . T , 2D -

F , . T R 2000, . B R 96. I

.

References

[1] Y. A , J. C . P . 24 (1977) 10.
[2] N.A. A , K. S , J. C . P . 127 (1996) 27.
[3] T.R. B , P. M , R. T , J. F M . 447 (2001) 179.
[4] T.R. B , O.M. A , J. F M . 499 (2004) 183.
[5] M.H. C , D. G , S. A , J. C . P . 108 (1993) 272.
[6] S.J. D , C.M. W , P . R . S . A 119 (1928) 92.
[7] P.G. D , W.H. R H S , C U P , C , UK, 1981.
[8] D. G , J.S. S , J. C . P . 138 (1997) 617.
[9] S.I. G , : S.I. G (E), F V , K A P , D , T N , 1995.
[10] B. G , H.O. K , A. S , M . C . 26 (1972) 649.
[11] Z. H , S. T ' , J. C . P . 114 (1994) 265.
[12] D.S. H , P. S , J. K , P . F A. 30 (1987) 2914.
[13] R.S. H , J. C . P . 19 (1975) 90.
[14] R. H , E. T , J. C . P . 158 (2000) 51.
[15] A. J , G.M. M , I . J. N . M E . 12 (1978) 141.
[16] J. J , J. F M . 218 (1990) 265.
[17] J. K , P. M , R. M , J. F M . 177 (1987) 133.
[18] Z. K , N A , S , N Y , 1966.
[19] H.P. K , H. E , P . F A 22 (1979) 1233.
[20] L.D. L , E.M. L , F M , . 6, P P , L , UK, 1959.
[21] S.K. L , J. C . P . 103 (1992) 16.
[22] T.T. L , T.K. S , M. C , E . F 37 (2004) 47.
[23] Z. L , C. L , C . F 23 (1994) 955.
[24] D. M , J.T. S , P . R . S . A 208 (1951) 517.
[25] P. M , J. K , J. F M . 118 (1982) 341.
[26] T.K. S , F C F D , U P , H I , 2004.
[27] T.K. S , G. G , S. D , J. C . P . 192 (2) (2003) 677.
[28] T.K. S , S. D , S. S , J. F M . 493 (2003) 277.
[29] T.K. S , A. D , J. S . C . 21 (1) (2004) 225.
[30] T.K. S , G. G , A. D , J. S . C . 21 (3) (2004) 253.
[31] T.K. S , S.K. S , A. D , J. S . C . 25 (2) (2005).
[32] T.K. S , M. C , Z.Y. W , K.S. Y , J. F S . 16 (1) (2002) 15.
[33] T.K. S , A. D , J. F M . 529 (2005) 147.
[34] L.N. T , SIAM R . 24 (2) (1982) 113.
[35] R.W.C.P. V , A.E.P. V , J. C . P . 187 (2003) 343.
[36] D.W. Z , SIAM J. S . C . 22 (2) (2000) 476.
[37] D.W. Z , H. L , H.M. J , SIAM J. S . C . 17 (1996) 328.
[38] X. Z , J. C . P . 144 (1998) 622.
[39] K.M. B , B.F. F , P . F A 4 (1992) 1637.
[40] S.C. R , D.S. H , J. F M . 252 (1993) 209.
[41] D.S. H , S.C. R , P . F 6 (1994) 1396.
[42] L.N. T , A.E. T , S.C. R , T.A. D , S 261 (1993) 578.
[43] M. H , T.R. B , D.S. H , J. F M . 481 (2003) 149.
[44] P.J. S D.S. H , S T S F , S , B , 2001.
[45] V.C. P , R. H J. F M . 38 (1969) 181.
[46] D.R. C , S.E. W , M.F. P , J. F M . 121 (1982) 487.
[47] B. H , C.W.H. D , J. W , F.T.M. N , H. F , B. E , H. W , R.R. K , F. W , S 305 (2004) 1594.
[48] M.A. R , P . R . L . 81 (11) (1998) 2244.