

付図・付表

Fig. 1) 一級海軍少佐 一ノ瀬 隆之助 (文相 29)



Fig. 11) 一級海軍少佐 一ノ瀬 隆之助 (文相 29)



Fig. 1.1 (a) BERPブレードの翼端平面形 (文献 [3])

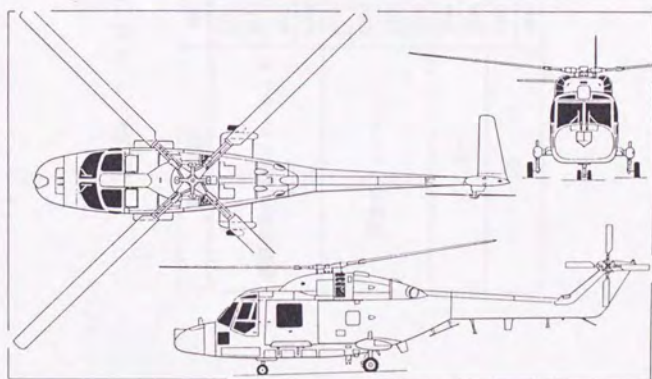


Fig. 1.1 (b) Lynx HAS. Mk2の3面図 (文献 [3])

Table 1.1 ヘリコプタの数値的解析法の発展

支配方程式	年	特徴	研究者
遷音速微小擾乱ポテンシヤル	1972	定常	Caradonna, Isom
	1975	非定常 (緩和法)	Caradonna, Isom
	1975	非定常 (時間線形化)	Ballhaus, Steger
	1978	非定常 (AF 法)	Caradonna, Piliippe
完全ポテンシヤル	1979	準定常、非保存型	Arieli, Tauber
	1984	準定常、非保存型	Chang
	1985	非定常、非保存型	Chang
	1986	非定常、保存型	Strawn
	1984	定常	Roberts, Murman
オイラー	1984	非定常	Sankar, Tung
	1987	定常、0 方程式モデル	Wake, Sankar
NS	1990	定常、2 方程式モデル	Aoyama, Kawachi, Saito

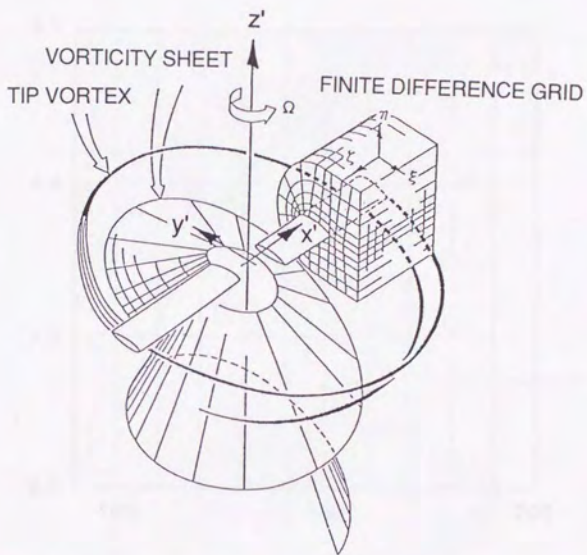


Fig. 3.1 座標系と計算格子及びホバリング時の後流形状

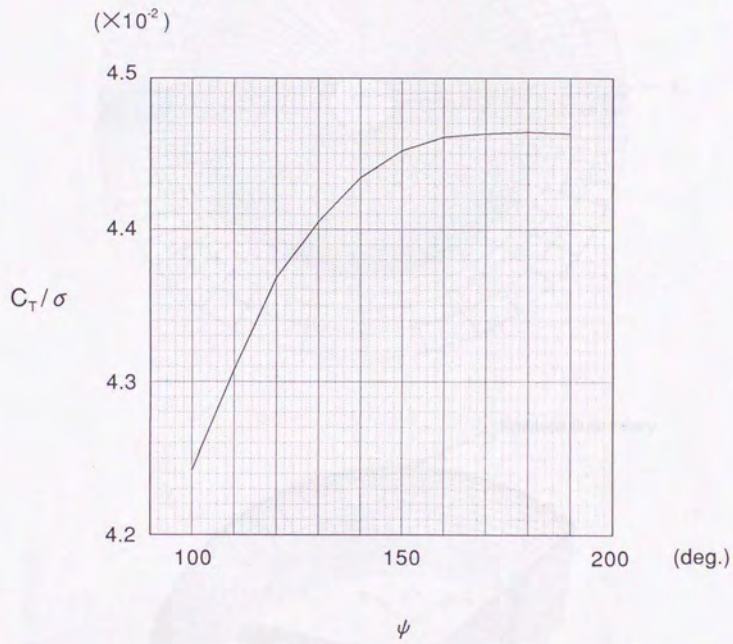


Fig. 3.2 C_T/σ の収束状況

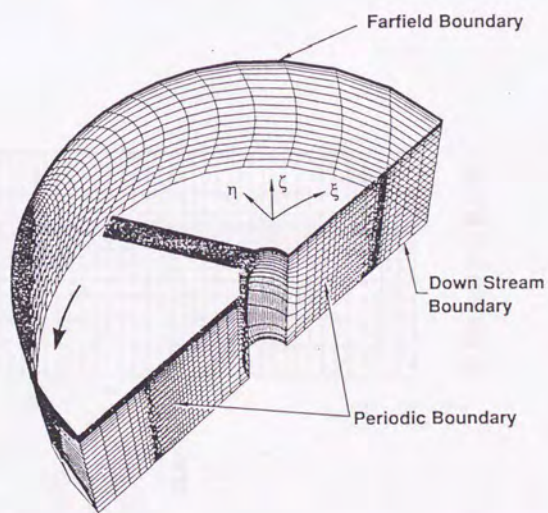
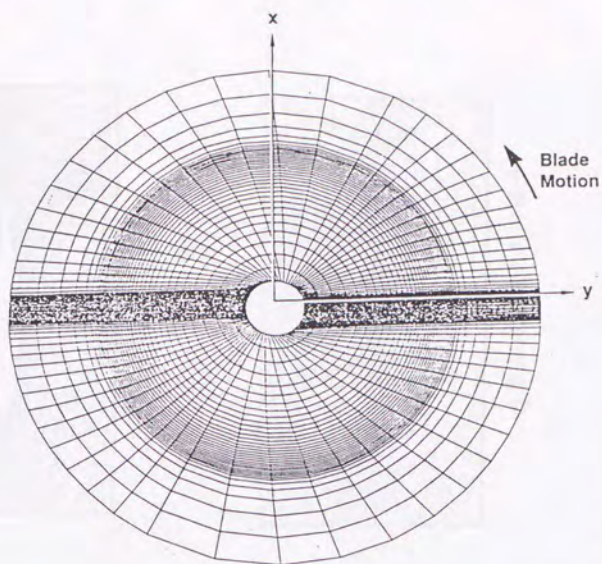
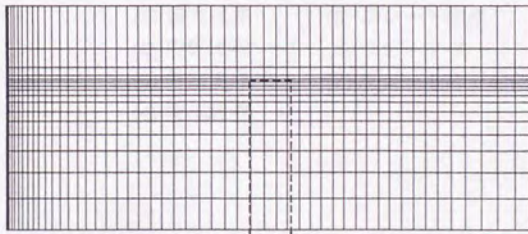
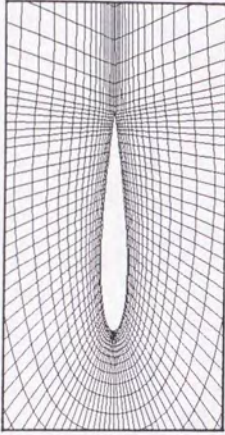


Fig. 3.3 ローター周を覆う格子 (文献 [51])

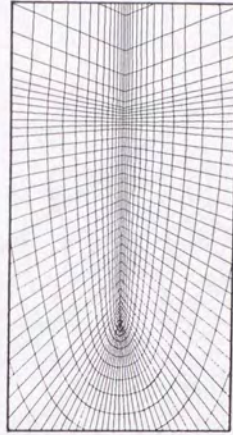


ブレード
+
回転中心

(a) Z軸方向から見た格子

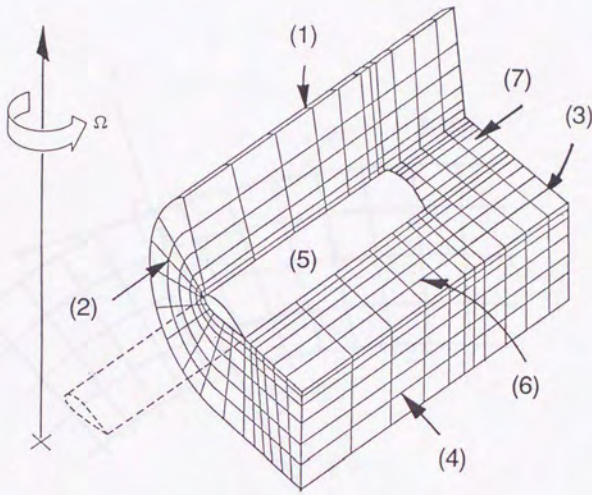


(b) 翼まわりの格子



(c) 厚み0の翼まわりの格子

Fig. 3.4 解析に用いた格子形状



- | | |
|----------|------------------|
| (1) 遠方境界 | (5) ブレード表面 |
| (2) 内側境界 | (6) ウェイク-カット |
| (3) 外側境界 | (7) ブレードの延長部分の境界 |
| (4) 流出境界 | |

Fig. 3.5 計算格子と境界

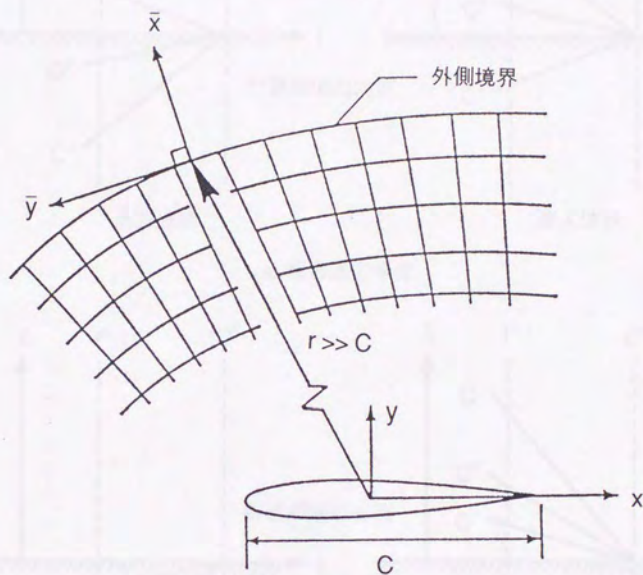
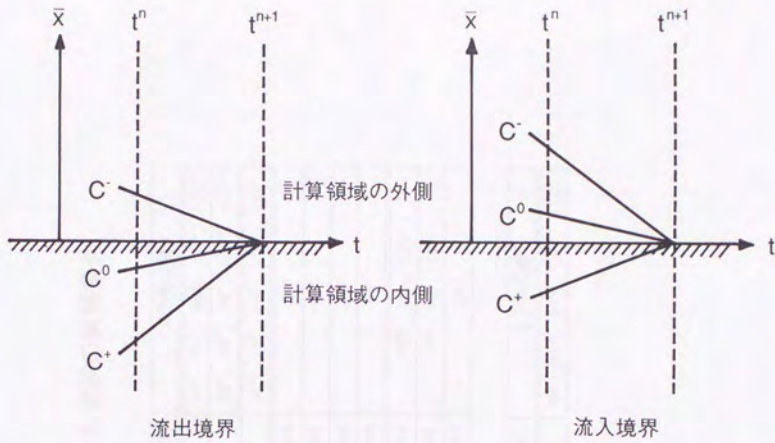
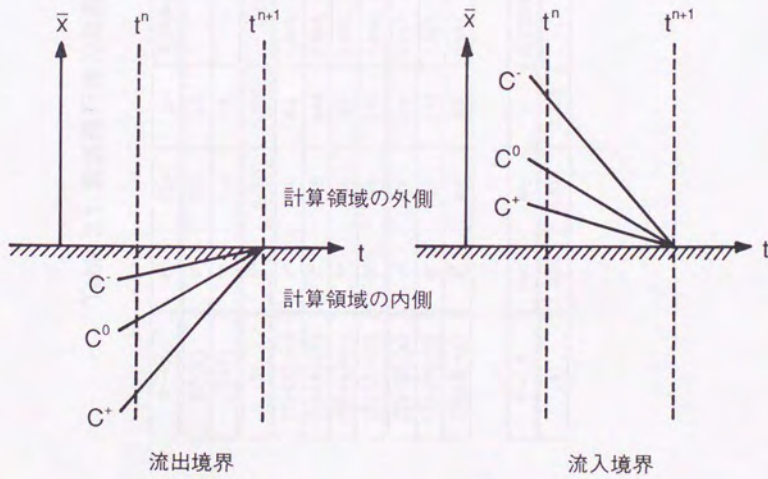


Fig. 3.6 外側境界における座標軸



(a) 亜音速の場合

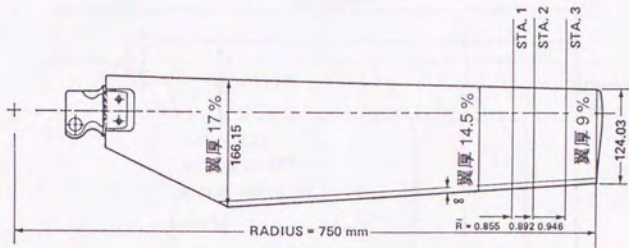


(b) 超音速の場合

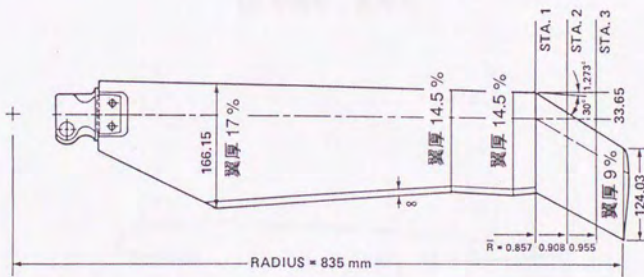
Fig. 3.7 特性曲線の様子

Table 3.1 前進飛行時の比較に用いた実験の実験条件

ケース	θ_c	M_T	μ	圧力計測位置 (r/R)	方位角位置
(1)-(a)	0°	0.7	0.3	0.893	30°, 60°, 90°, 120°, 150°
(1)-(b)	0°	0.8	0.2	0.893	30°, 60°, 90°, 120°, 150°
(2)	0°	0.763	0.246	0.876, 0.946	30°, 60°, 90°, 120°, 150°
(3)-(A)-(a)	0°	0.6	0.4	0.855, 0.892, 0.946	90°
(3)-(A)-(b)	0°	0.6	0.45	0.855, 0.892, 0.946	90°
(3)-(A)-(c)	0°	0.6	0.5	0.855, 0.892, 0.946	90°
(3)-(A)-(d)	0°	0.6	0.55	0.855, 0.892, 0.946	90°
(3)-(B)-(a)	0°	0.6	0.4	0.857, 0.908, 0.955	60°, 90°, 120°
(3)-(B)-(b)	0°	0.6	0.45	0.857, 0.908, 0.955	60°, 90°, 120°
(3)-(B)-(c)	0°	0.6	0.5	0.857, 0.908, 0.955	90°
ケース	C_T/σ	M_T	μ <td>圧力計測位置 (r/R)</td> <td>方位角位置</td>	圧力計測位置 (r/R)	方位角位置
(4)	0.05	0.629	0.362	0.85	30°, 60°, 90°, 120°, 150°

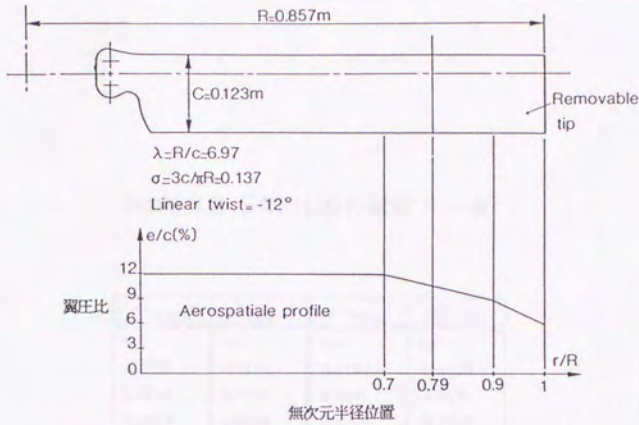


(a) 形状 (A)

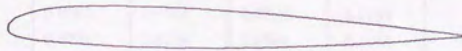


(b) 形状 (B)

Fig. 3.8 ONERAの実験（揚力なし）で用いられたブレード形状



(a) 平面形と翼厚比

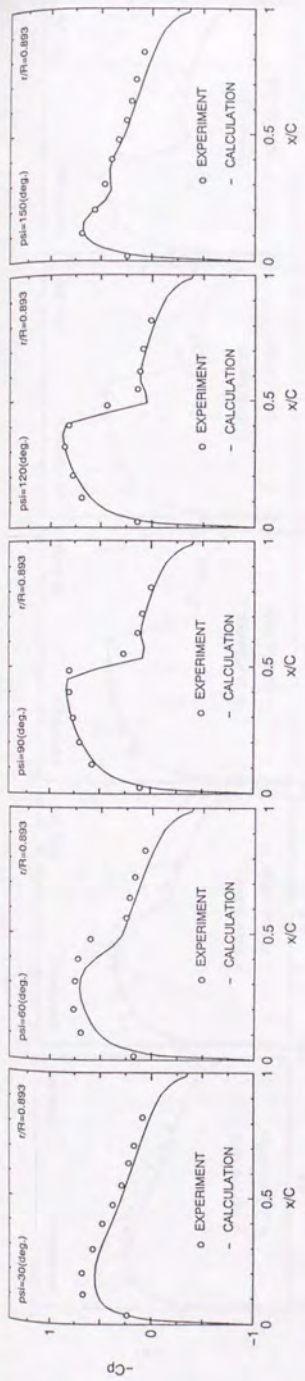


(b) SA13109の翼型形状

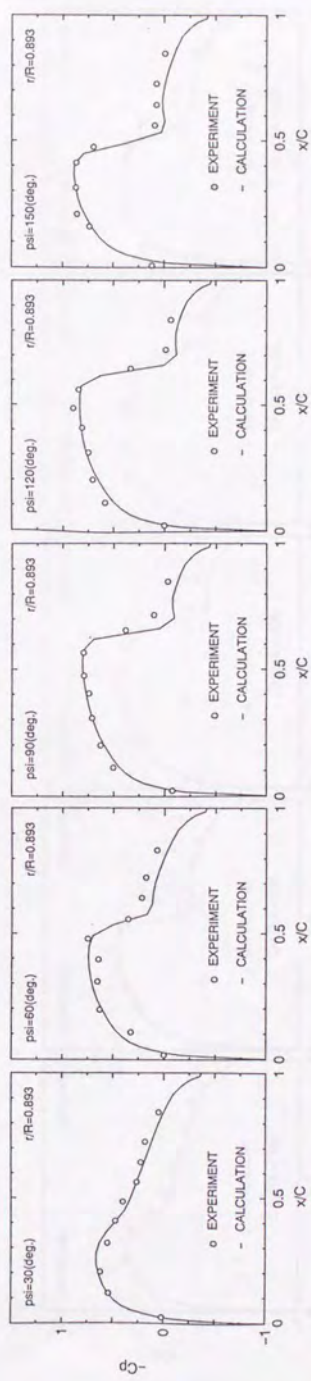
Fig. 3.9 ONERAの実験（揚力あり）で用いられたブレード形状

Table 3.2 SA13109の翼型データ

x/c_{upper}	y/c_{upper}	x/c_{lower}	y/c_{lower}
0.0	0.0	0.0	0.0
0.0100	0.0192	0.0150	-0.0153
0.0221	0.0268	0.0280	-0.0194
0.0472	0.0365	0.0528	-0.0237
0.0729	0.0429	0.0771	-0.0262
0.0986	0.0472	0.1014	-0.0280
0.1500	0.0519	0.1500	-0.0311
0.2007	0.0535	0.1993	-0.0337
0.2508	0.0537	0.2492	-0.0357
0.3008	0.0531	0.2992	-0.0369
0.4007	0.0503	0.3993	-0.0374
0.5006	0.0454	0.4994	-0.0358
0.6005	0.0387	0.5995	-0.0321
0.7003	0.0306	0.6997	-0.0265
0.8002	0.0214	0.7998	-0.0194
0.9001	0.0114	0.8999	-0.0108
0.9500	0.0062	0.9500	-0.0060
1.0	0.0009	1.0	-0.0009

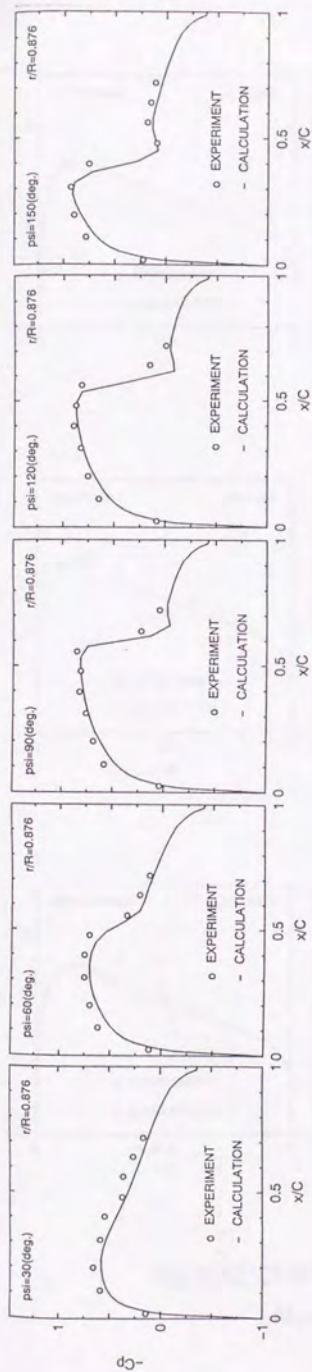


(a) $M_T = 0.7$, $\mu = 0.3$, $r/R = 0.893$

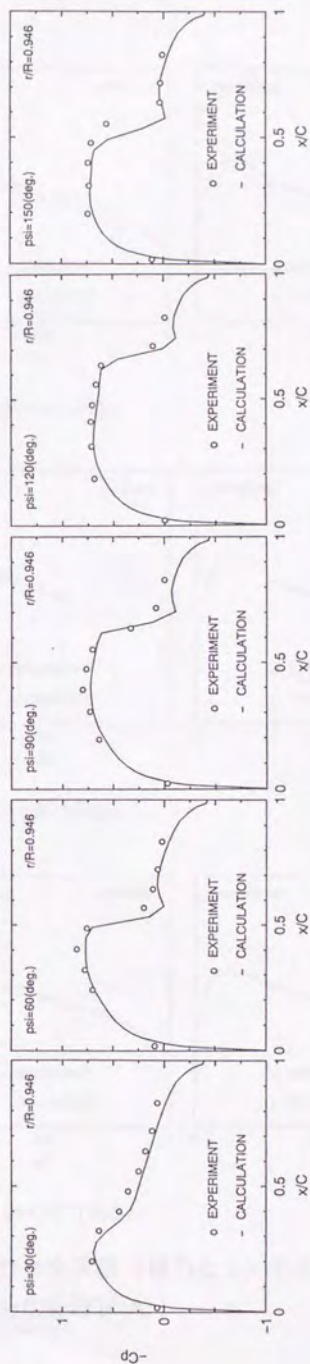


(b) $M_T = 0.8$, $\mu = 0.2$, $r/R = 0.893$

Fig. 3.10 NASAで行われた実験との比較

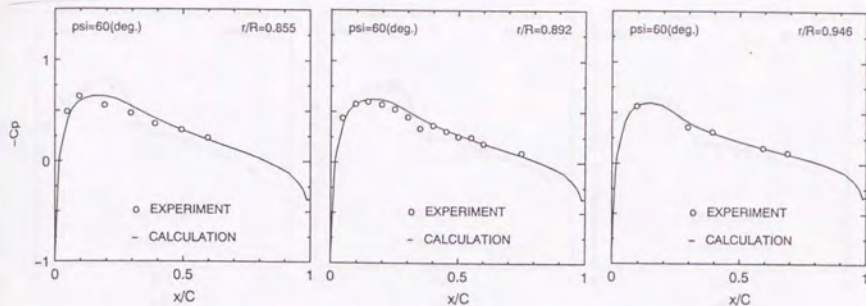


(a) $M_T = 0.763$, $\mu = 0.246$, $r/R = 0.876$

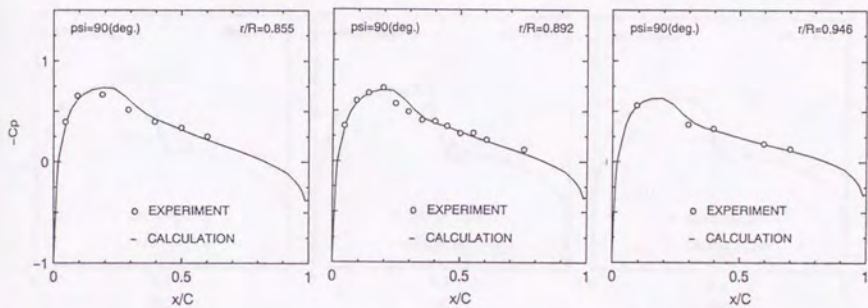


(b) $M_T = 0.763$, $\mu = 0.246$, $r/R = 0.946$

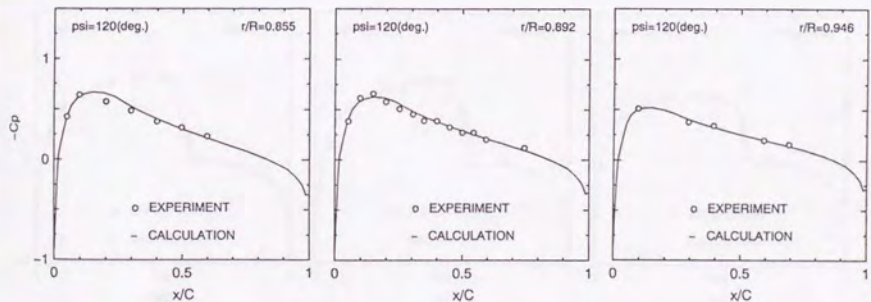
Fig. 3.11 AFDDで行われた実験との比較



(a) $\psi = 60$ (deg.)

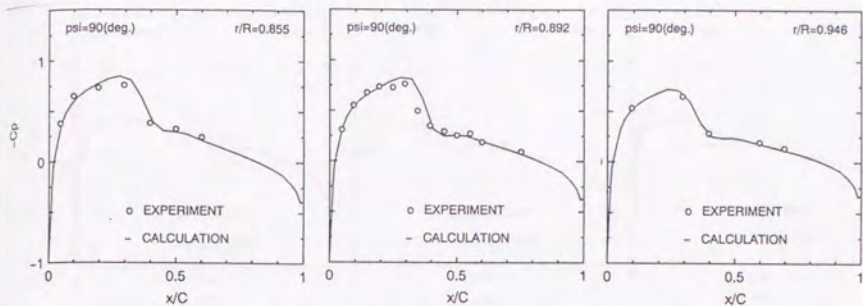


(b) $\psi = 90$ (deg.)

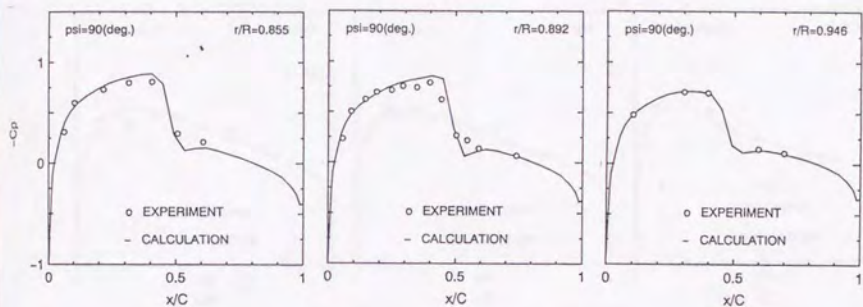


(c) $\psi = 120$ (deg.)

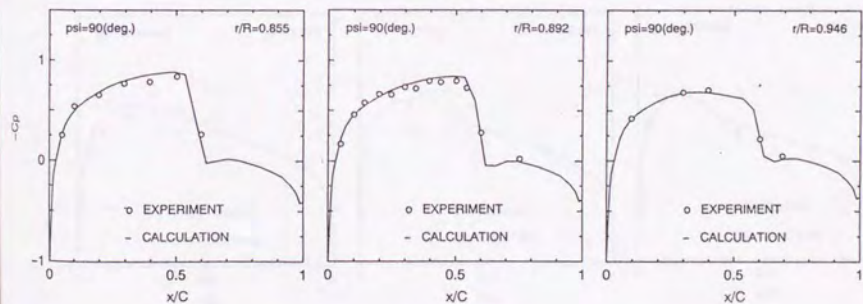
Fig. 3.12 ONERAで行われた実験（揚力なし）との比較
($M_T = 0.6$, $\mu = 0.4$, 形状(A))



(a) $M_T = 0.6, \mu = 0.45$

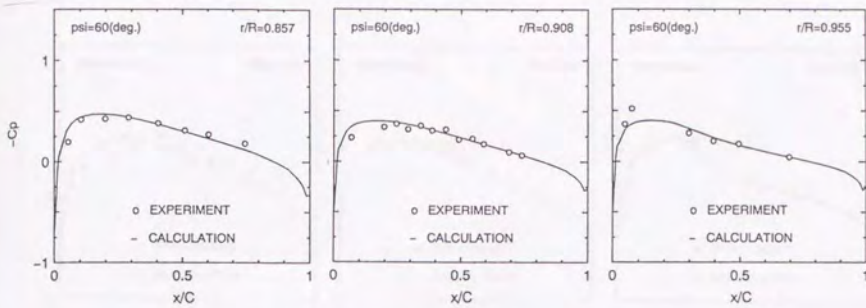


(b) $M_T = 0.6, \mu = 0.50$

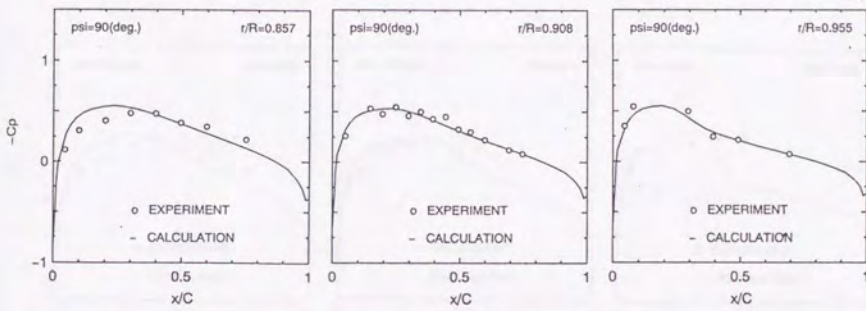


(c) $M_T = 0.6, \mu = 0.55$

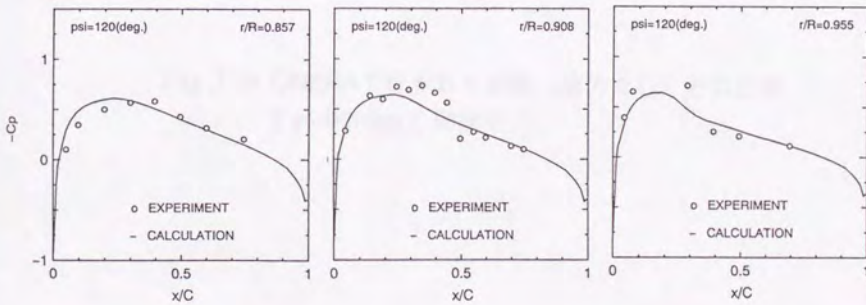
Fig. 3.13 ONERAで行われた実験 (揚力なし) との比較
($\psi = 90(\text{deg.})$, 形状(A))



(a) $\psi = 60$ (deg.)

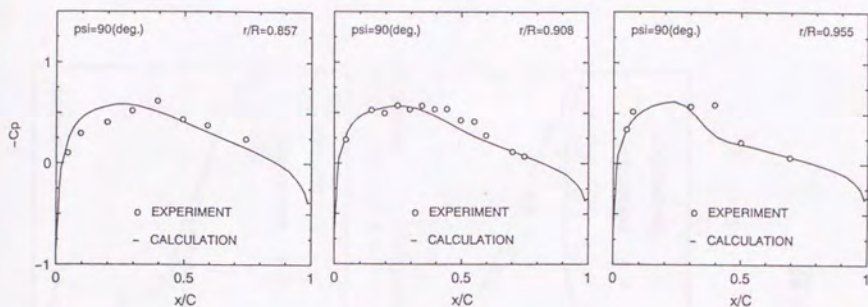


(b) $\psi = 90$ (deg.)

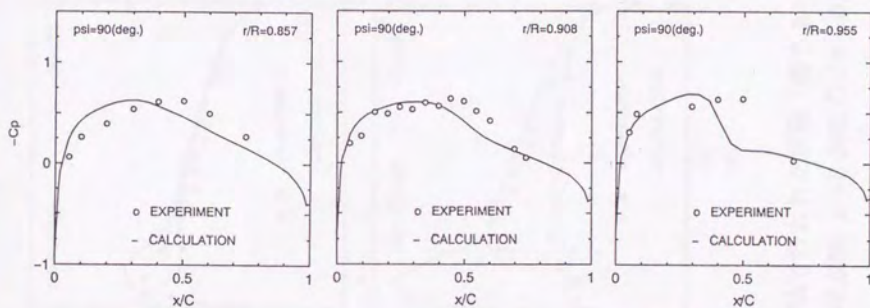


(c) $\psi = 120$ (deg.)

Fig. 3.14 ONERAで行われた実験（揚力なし）との比較
 ($M_T = 0.6$, $\mu = 0.4$, 形状(B))



(a) $M_T = 0.6, \mu = 0.45$



(b) $M_T = 0.6, \mu = 0.50$

Fig. 3.15 ONERAで行われた実験 (揚力なし) との比較
($\psi=90(\text{deg})$, 形状(B))

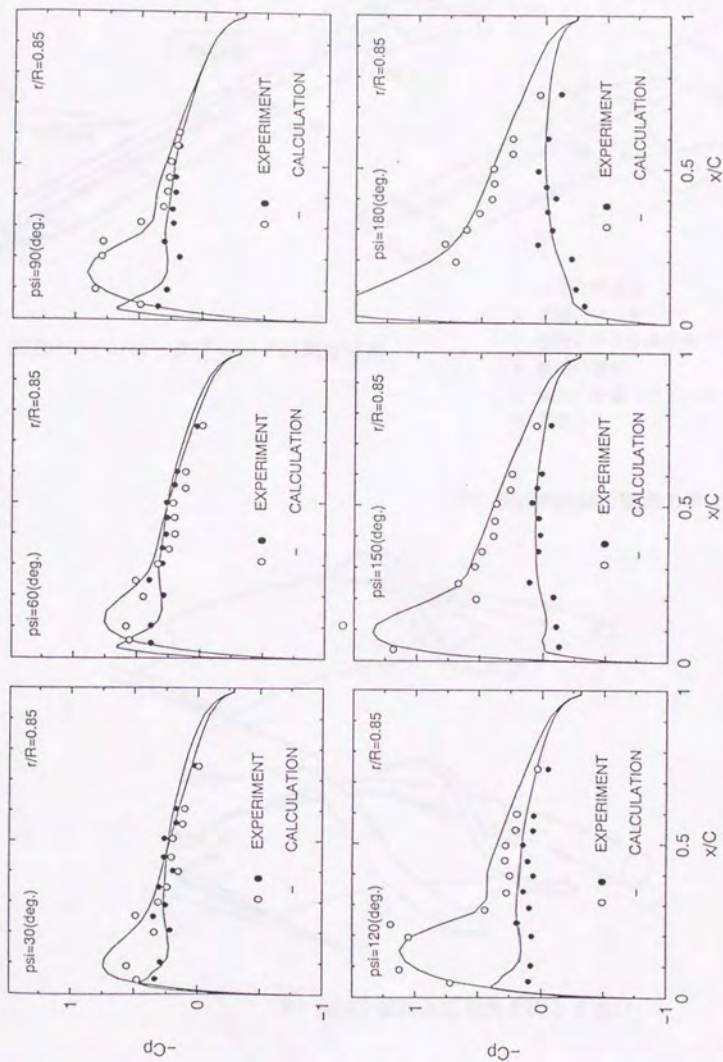
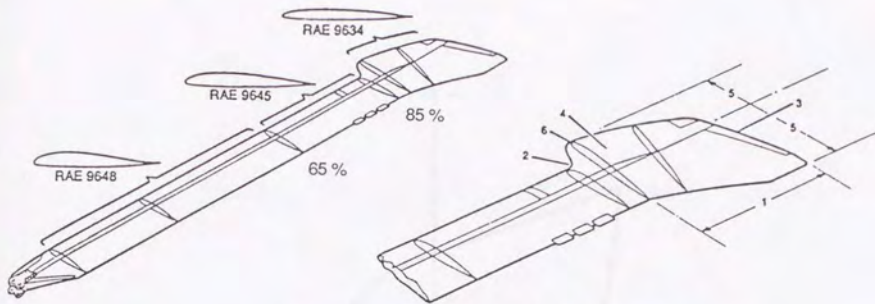


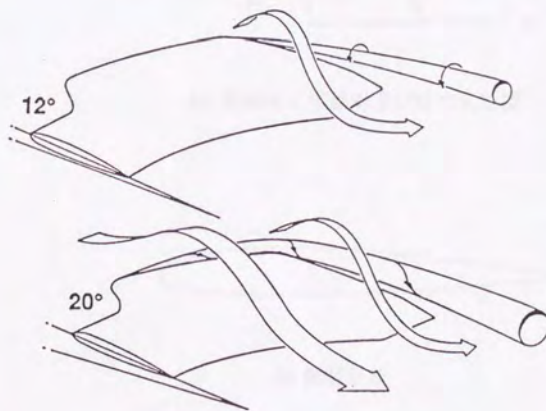
Fig. 3.16 ONERAで行われた実験 (揚力あり) との比較
 ($M_T = 0.629$, $\mu = 0.362$, $C_T/\sigma = 0.05$)



(a) BERPメインロータブレードの翼型分布

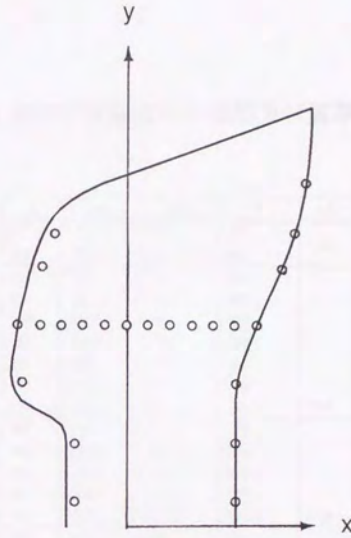
1. 大きな後退角
2. 前線のノッチ
3. 極度に大きな後退角
4. 面積の増加
5. 揚力と質量のバランス
6. 薄翼

(b) BERP翼端の空気力学上の特徴

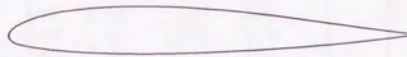


(c) BERP翼端の高迎角でのふるまい

Fig. 3.17 BERP翼端の特徴 (文献 [2])



(a) 座標系と平面形及び圧力孔位置

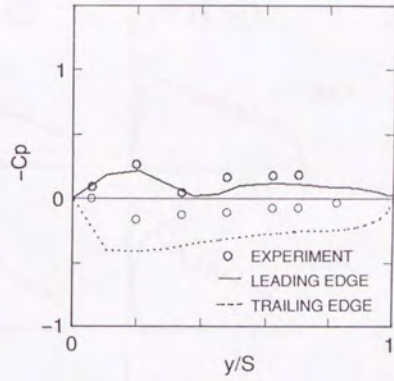
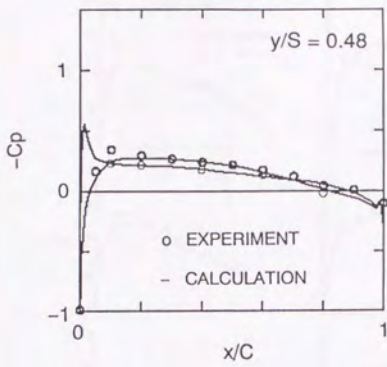


(b) 翼型形状

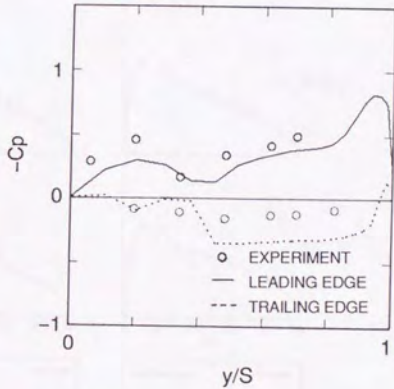
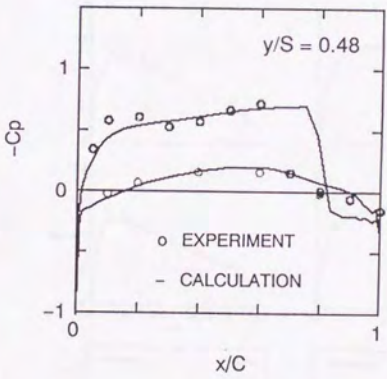
Fig. 3.18 KHIのBERP状翼端の幾何形状

Table 3.3 BERP状翼端の平面形及び翼厚分布のデータ

y	x_{LE}	x_{TE}	C	i/C
0	-70	130	200	
100	-70	130	200	0.12
110	-71	130	201	
120	-75	130	205	
130	-87	130	217	
140	-106	130	236	
150	-122	130	252	
160	-129	131	260	
170	-132.5	132	264.5	0.09
180	-134	134	268	
190	-133.5	136.5	270	
200	-132.5	140	272.5	
220	-129	147.5	276.5	
240	-126	155.5	281.5	0.08
260	-122	164	286	
280	-117	173	290	
300	-113	181.5	294.5	
310	-110	185.5	295.5	
320	-107.5	189.5	297	
330	-104	193.5	297.5	0.06
340	-100.5	197	297.5	
350	-96.5	200	296.5	
360	-91	203	294	
370	-85	205.5	290.5	
380	-76.5	207.5	284	
390	-64.5	209.5	274	
400	-48.5	211.5	260	
410	-28	213	241	0.05
430	26.89	215.5	188.61	
460	109.22	218	108.78	
480	164.11	219	54.89	
500	219	219	0	



(a) $M_\infty = 0.6$, $\theta_c = -0.55$ (deg.)



(b) $M_\infty = 0.898$, $\theta_c = 4.37$ (deg.)

Fig. 3.19 BERP状翼端の実験との比較

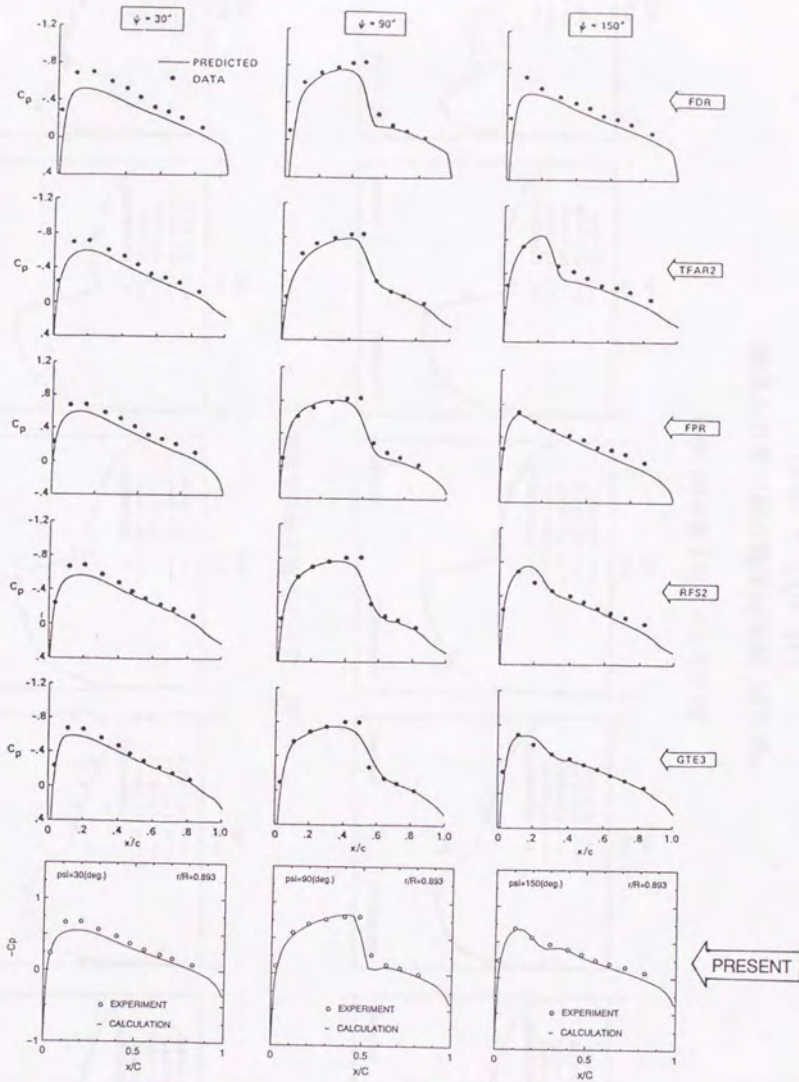
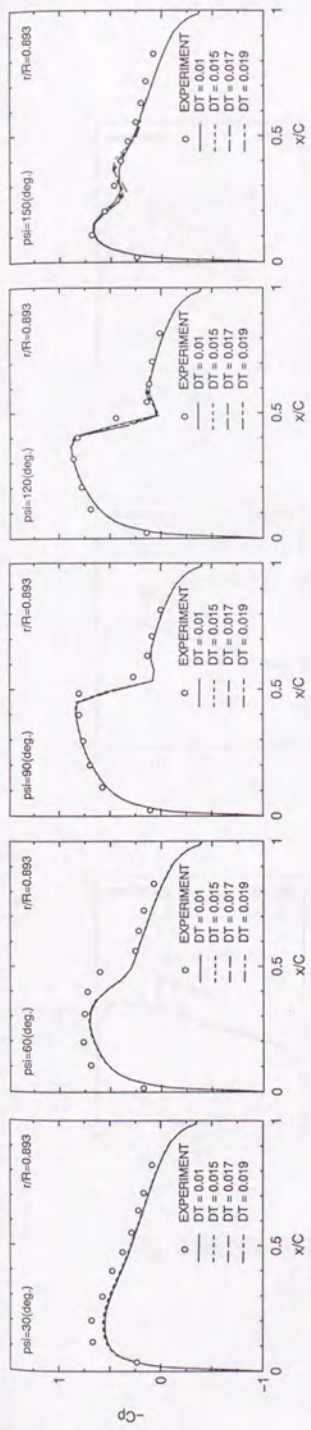
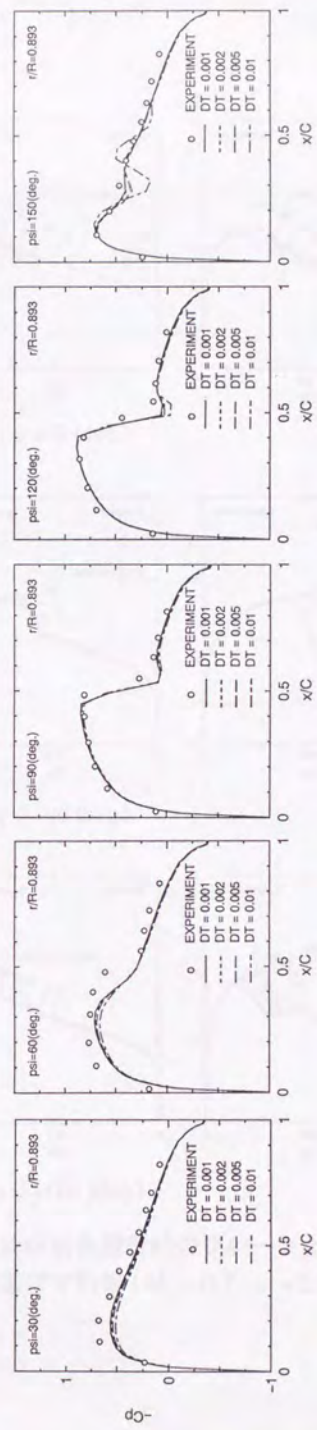


Fig. 3.20 他の解析法の結果との比較
 ($M_T = 0.7$, $\mu = 0.3$)

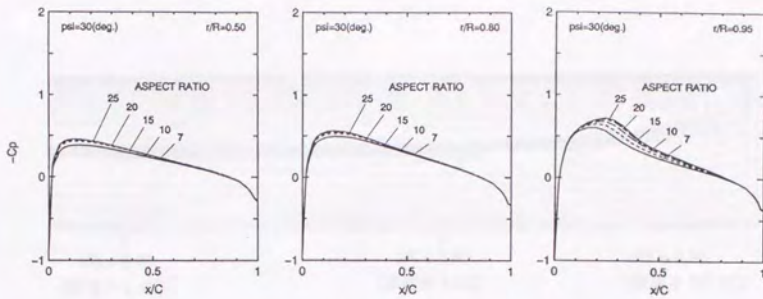


(a) ニュートン法を使った場合

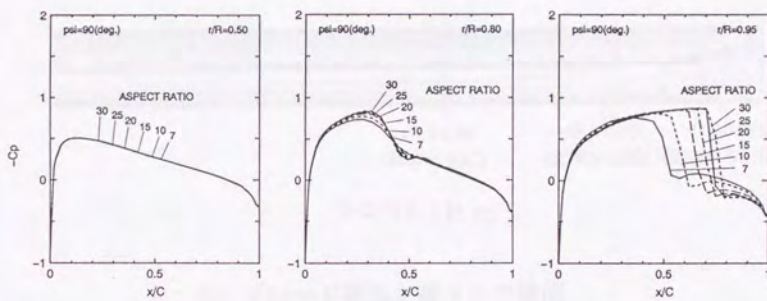


(b) ニュートン法を使わない場合

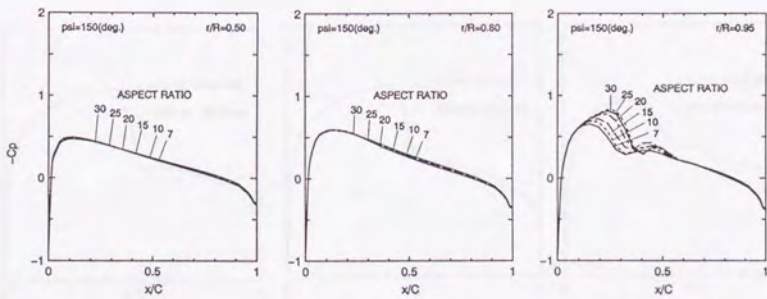
Fig. 3.21 時刻幅が解に及ぼす影響
($M_T = 0.7, \mu = 0.3$)



(1) $\psi = 30$ (deg.)

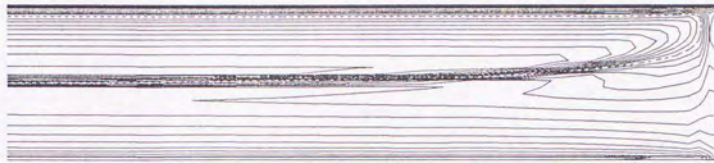


(2) $\psi = 90$ (deg.)



(3) $\psi = 150$ (deg.)

Fig. 3.22 (a) アスペクト比が前進飛行時のブレード上
圧力分布に及ぼす影響 ($M_T = 0.7$, $\mu = 0.3$)

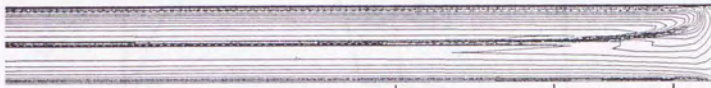


$r/R = 0.60$
(翼端から4C)

$r/R = 0.80$
(翼端から2C)

$r/R = 0.95$
(翼端から0.5C)

アスペクト比 10



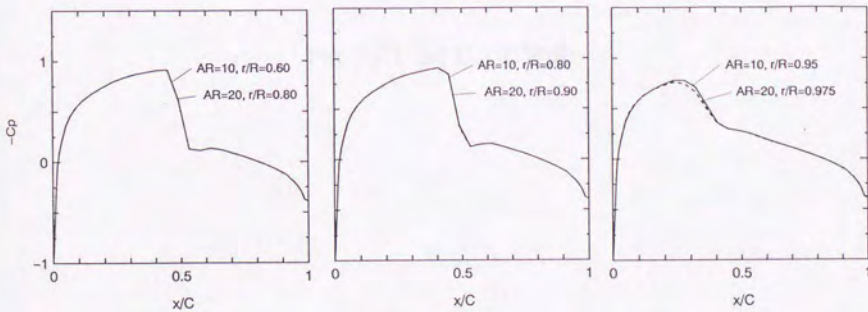
$r/R = 0.80$
(翼端から4C)

$r/R = 0.90$
(翼端から2C)

$r/R = 0.975$
(翼端から0.5C)

アスペクト比 20

(1) ブレード翼面上等マッハ線図



(2) ブレード翼面上圧力分布

Fig. 3.22 (b) アスペクト比が非回転時のブレード上
圧力分布に及ぼす影響

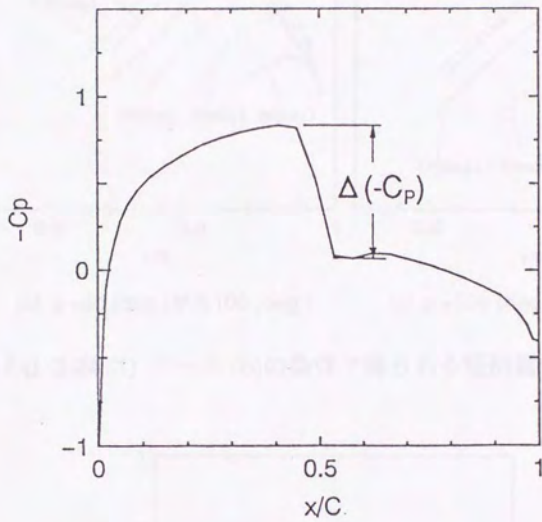
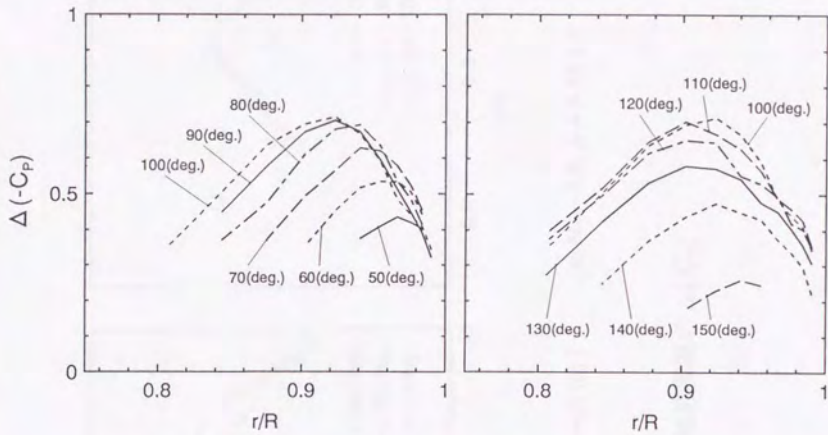


Fig. 3.23 $\Delta(-C_p)$ の定義



(a) $\psi = 50$ (deg.) から 100 (deg.) (b) $\psi = 100$ (deg.) から 150 (deg.)

Fig. 3.24 (1) ケース (b)の条件で得られる矩形翼端の $\Delta(-C_p)$

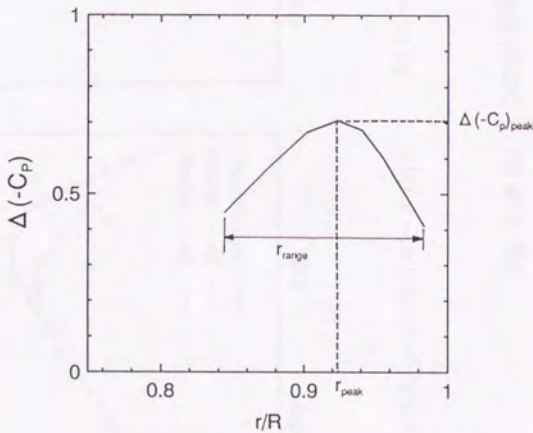
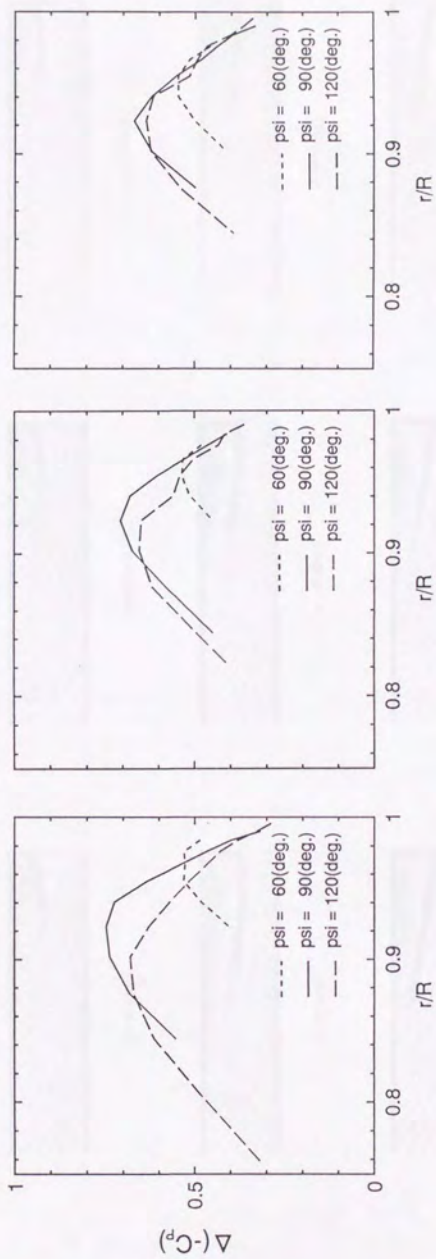


Fig. 3.24 (2) $\Delta(-C_p)_{\text{peak}}$, r_{peak} , r_{range} の定義

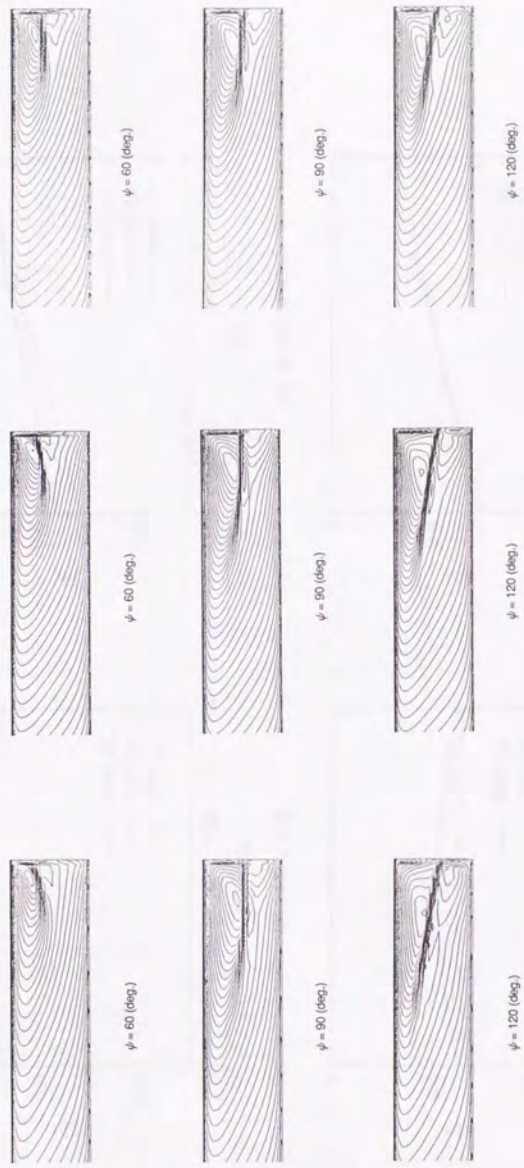


(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]

(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

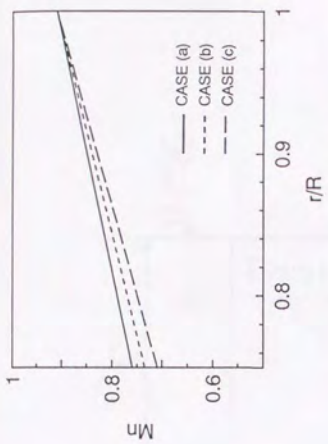
(c) $M_T = 0.8$, $\mu = 0.14$ [ケース (c)]

Fig. 3.24 (3) 3つの計算条件で得られる矩形翼端の $\Delta(-C_p)$

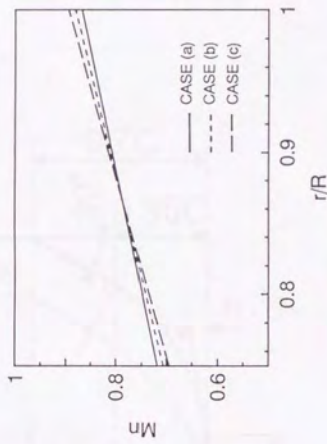


(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)] (b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)] (c) $M_T = 0.8$, $\mu = 0.14$ [ケース (c)]

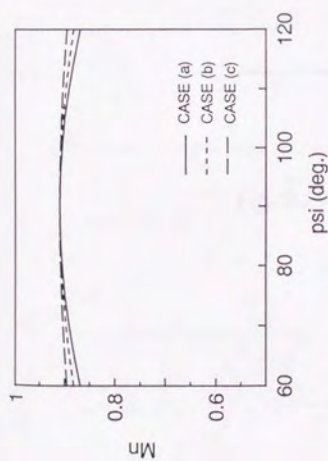
Fig. 3.25 3つの計算条件で得られる矩形翼端の
ブレード翼面上等マッハ線図



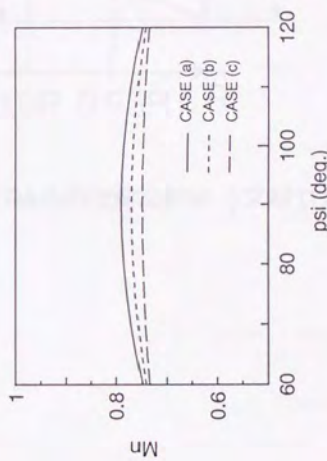
(a) $r/R = 1.0$



(b) $r/R = 0.8$



(c) $\psi = 90$ (deg.)



(d) $\psi = 60, 120$ (deg.)

Fig. 3.26 翼素に垂直な速度成分 M_n の変化

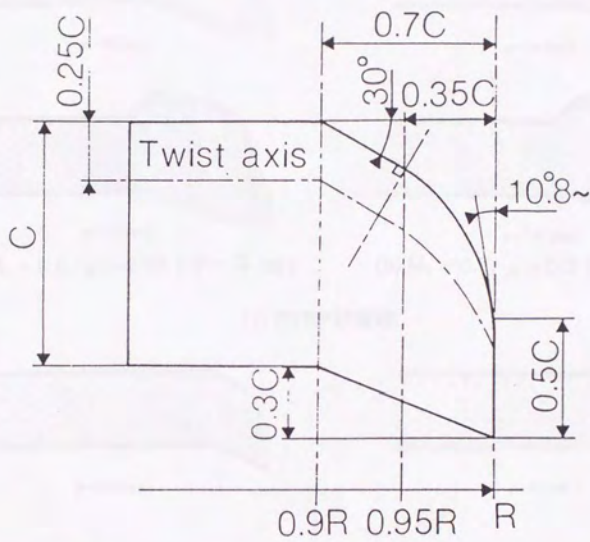
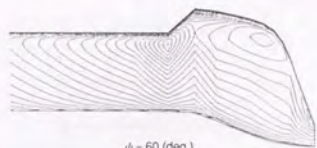


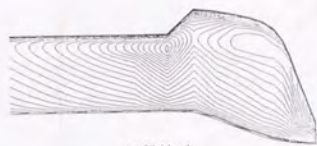
Fig. 3.27 ONERAのPF2翼端形状 (文献 [11])



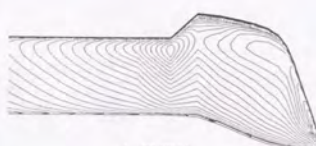
$\psi = 60$ (deg.)



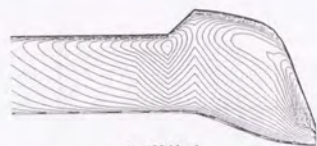
$\psi = 60$ (deg.)



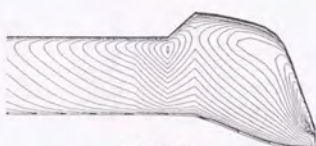
$\psi = 90$ (deg.)



$\psi = 90$ (deg.)



$\psi = 120$ (deg.)



$\psi = 120$ (deg.)

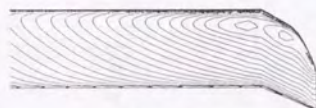
(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]

(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

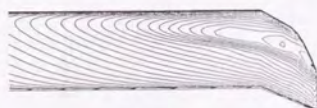
(1) BERP状翼端



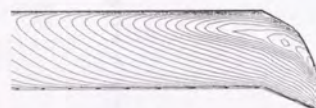
$\psi = 60$ (deg.)



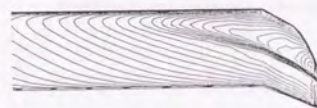
$\psi = 60$ (deg.)



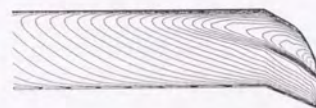
$\psi = 90$ (deg.)



$\psi = 90$ (deg.)



$\psi = 120$ (deg.)



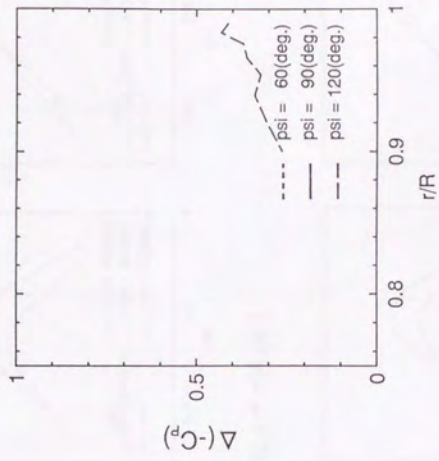
$\psi = 120$ (deg.)

(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]

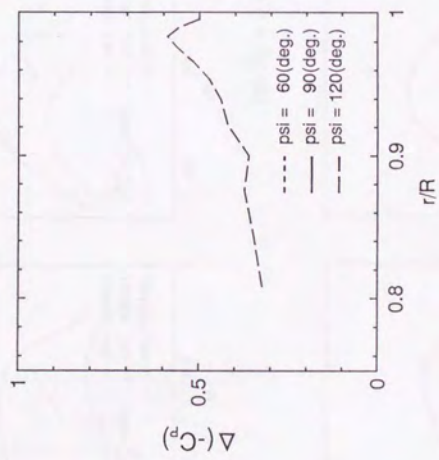
(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

(2) PF2状翼端

Fig. 3.28 先進的翼端のブレード翼面上等マッハ線図

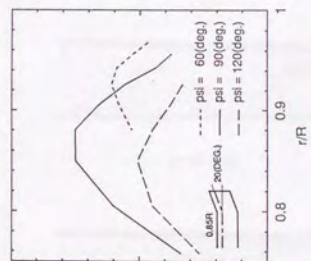
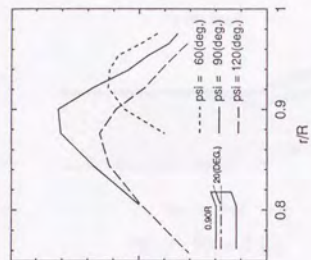
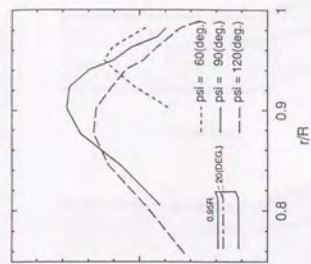


(a) $M_\infty = 0.6, \mu = 0.52$ [ケース (a)]

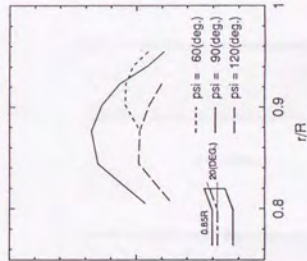
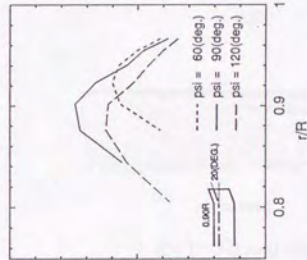
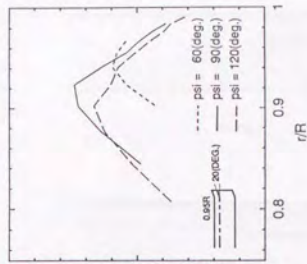


(b) $M_\infty = 0.7, \mu = 0.3$ [ケース (b)]

Fig. 3.29 PF2翼端の $\Delta(-C_p)$

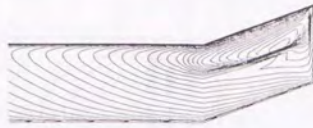


(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]



(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

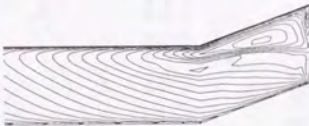
Fig. 3.30 翼端に前進角を付けたときの $\Delta(-C_p)$



$\psi = 60$ (deg.)



$\psi = 90$ (deg.)

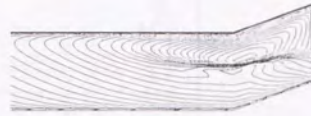


$\psi = 120$ (deg.)

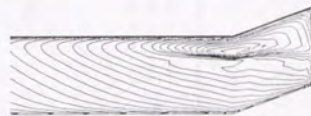
(a) $(r/R)_0 = 0.80$



$\psi = 60$ (deg.)

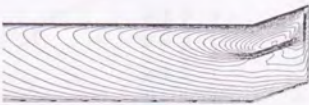


$\psi = 90$ (deg.)

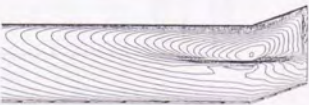


$\psi = 120$ (deg.)

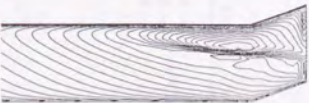
(b) $(r/R)_0 = 0.85$



$\psi = 60$ (deg.)



$\psi = 90$ (deg.)

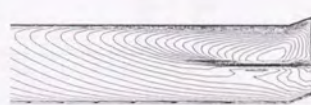


$\psi = 120$ (deg.)

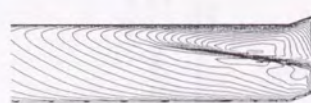
(c) $(r/R)_0 = 0.90$



$\psi = 60$ (deg.)



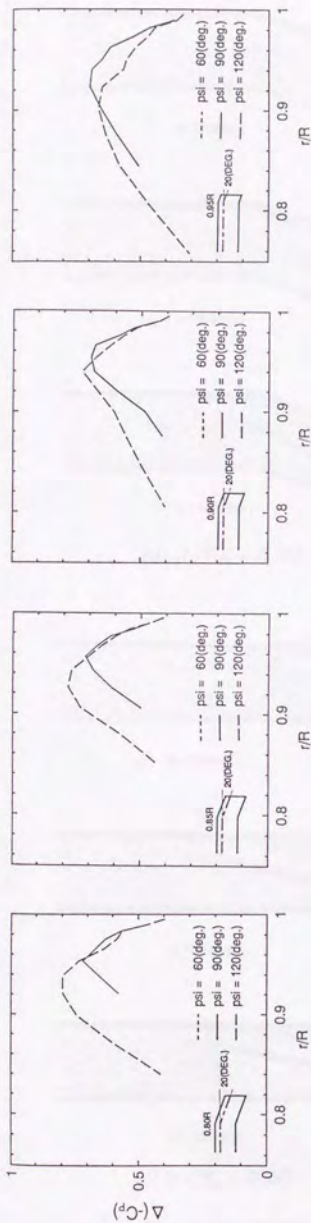
$\psi = 90$ (deg.)



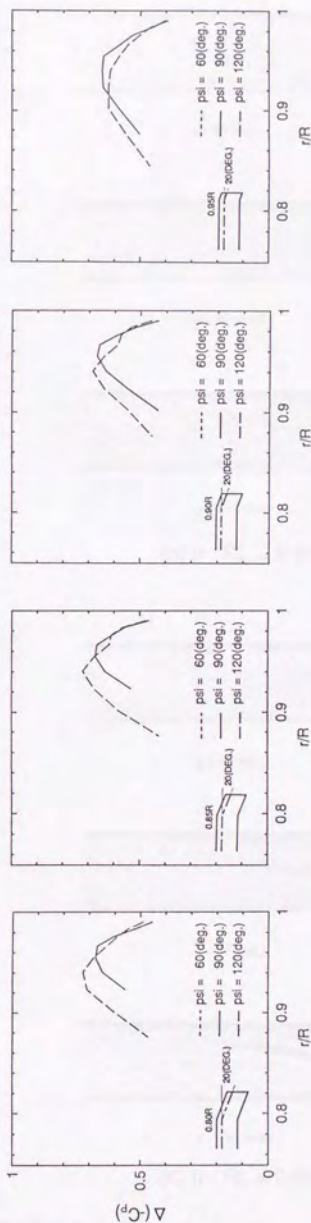
$\psi = 120$ (deg.)

(d) $(r/R)_0 = 0.95$

Fig. 3.31 翼端に前進角を付けたときのブレード
翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)

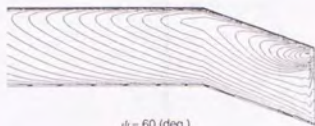


(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]



(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

Fig. 3.32 翼端に後退角を付けたときの $\Delta(-C_p)$



$\psi = 60 \text{ (deg.)}$

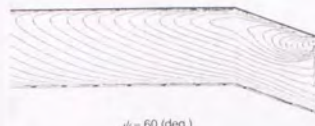


$\psi = 90 \text{ (deg.)}$

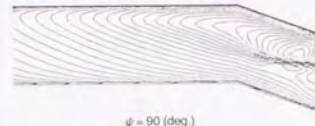


$\psi = 120 \text{ (deg.)}$

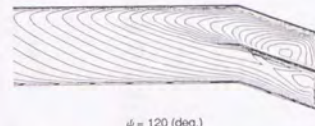
(a) $(r/R)_0 = 0.80$



$\psi = 60 \text{ (deg.)}$

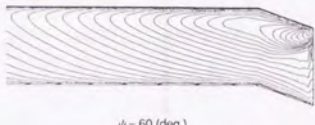


$\psi = 90 \text{ (deg.)}$

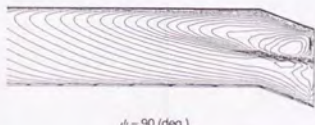


$\psi = 120 \text{ (deg.)}$

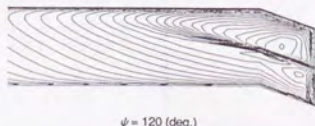
(b) $(r/R)_0 = 0.85$



$\psi = 60 \text{ (deg.)}$

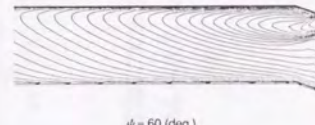


$\psi = 90 \text{ (deg.)}$

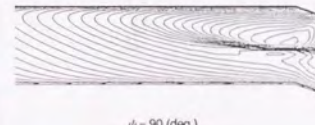


$\psi = 120 \text{ (deg.)}$

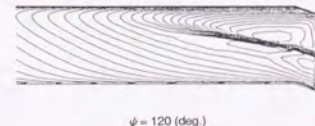
(c) $(r/R)_0 = 0.90$



$\psi = 60 \text{ (deg.)}$



$\psi = 90 \text{ (deg.)}$



$\psi = 120 \text{ (deg.)}$

(d) $(r/R)_0 = 0.95$

Fig. 3.33 翼端に後退角を付けたときのブレード
翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)

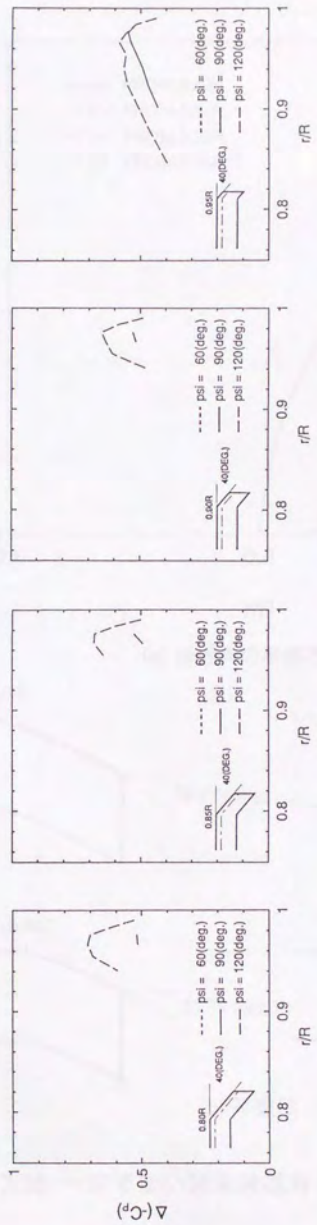
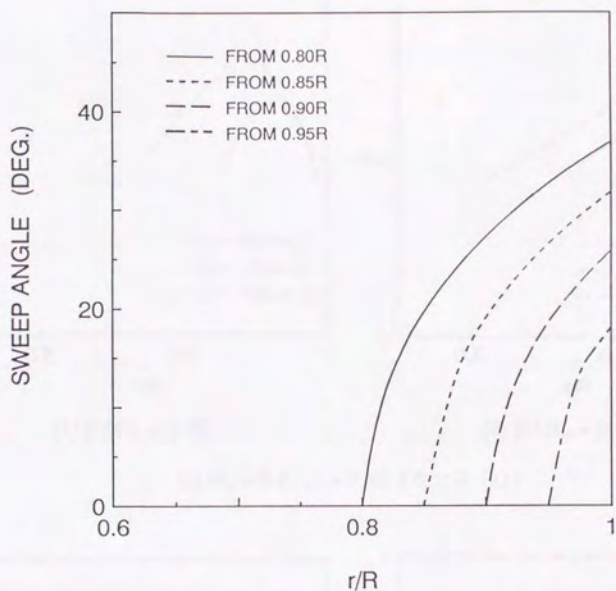
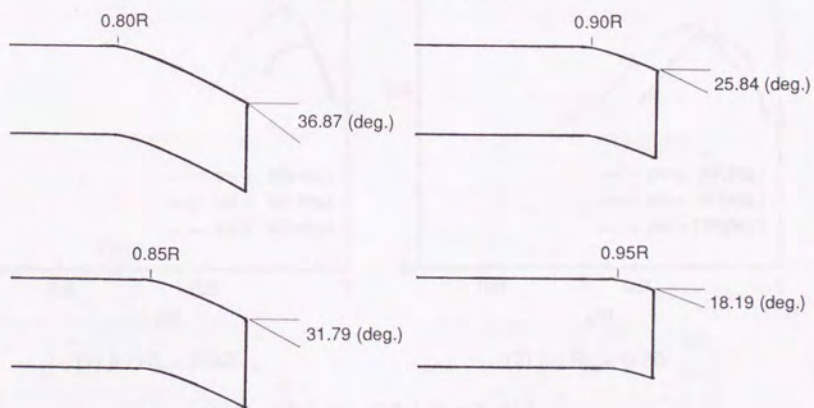


Fig. 3.34 翼端に大きな後退角を付けたときの $\Delta(-C_p)$
 ($M_T = 0.7, \mu = 0.3$)

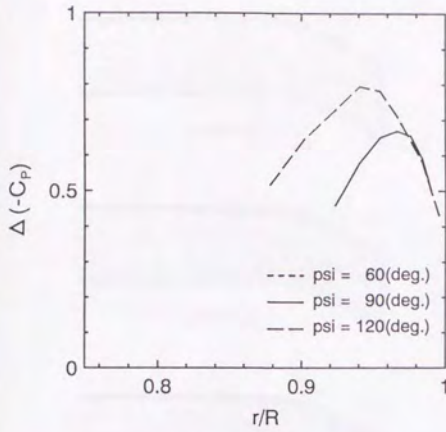


(a) 後退角の半径方向分布

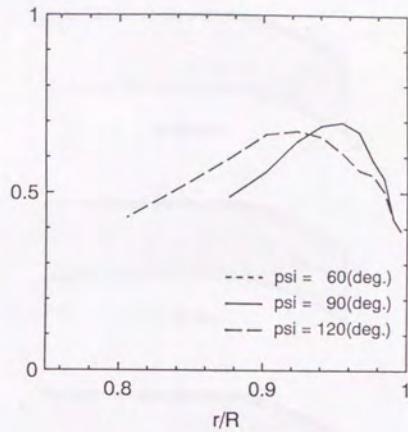


(b) 平面形

Fig. 3.35 一定でない翼端後退角を持つブレードの形状

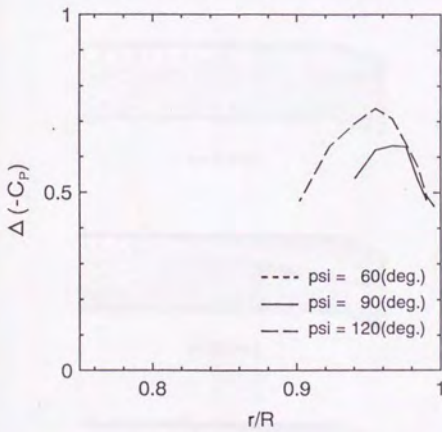


(1) $(r/R)_0 = 0.80$

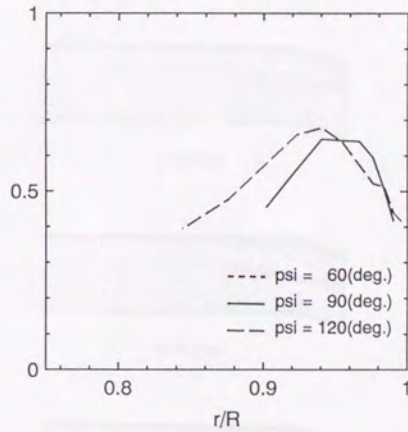


(2) $(r/R)_0 = 0.90$

(a) $M_T = 0.6, \mu = 0.52$ [ケース (a)]



(1) $(r/R)_0 = 0.80$



(2) $(r/R)_0 = 0.90$

(b) $M_T = 0.7, \mu = 0.3$ [ケース (b)]

Fig. 3.36 翼端に一定でない後退角を付けたときの $\Delta(-C_p)$

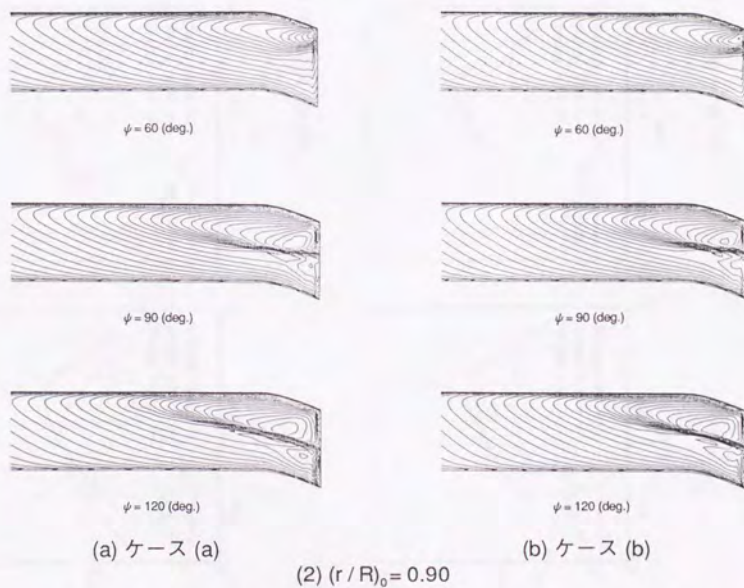
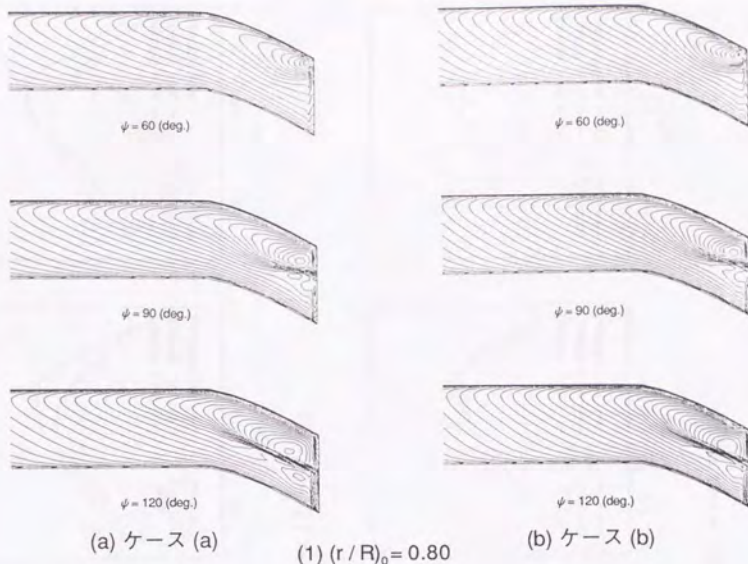
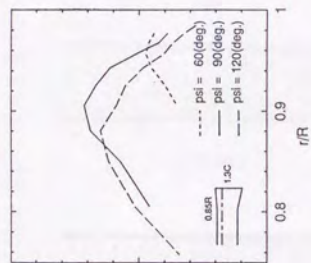
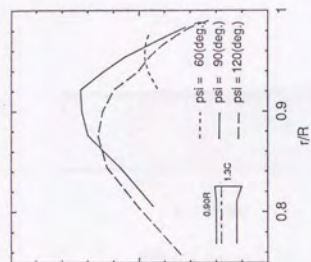
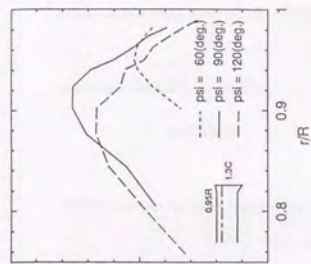
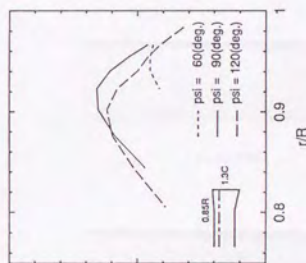
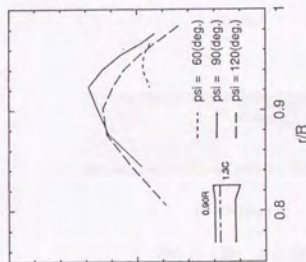
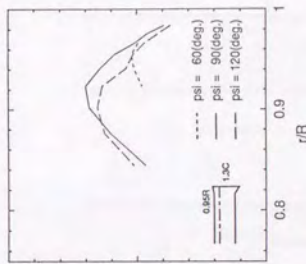


Fig. 3.37 翼端に一定でない後退角を付けたときのブレード翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)



(a) $M_T = 0.6$, $\mu = 0.52$ [ケース (a)]



(b) $M_T = 0.7$, $\mu = 0.3$ [ケース (b)]

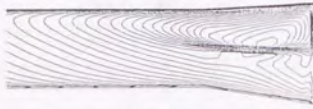
Fig. 3.38 翼端に逆テーパを付けたときの $\Delta(-C_p)$



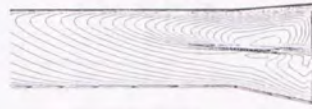
$\psi = 60$ (deg.)



$\psi = 60$ (deg.)



$\psi = 90$ (deg.)



$\psi = 90$ (deg.)



$\psi = 120$ (deg.)



$\psi = 120$ (deg.)

(a) $(r/R)_0 = 0.80$

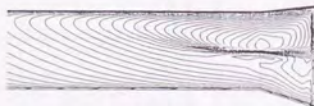
(b) $(r/R)_0 = 0.85$



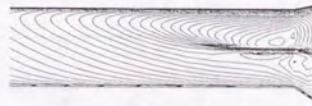
$\psi = 60$ (deg.)



$\psi = 60$ (deg.)



$\psi = 90$ (deg.)



$\psi = 90$ (deg.)



$\psi = 120$ (deg.)

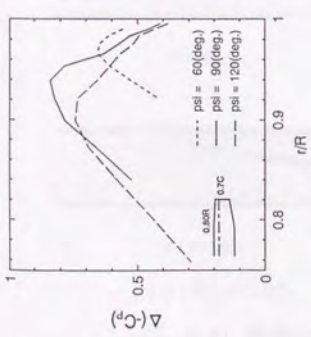
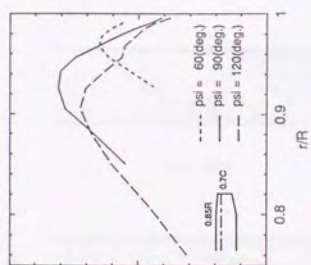
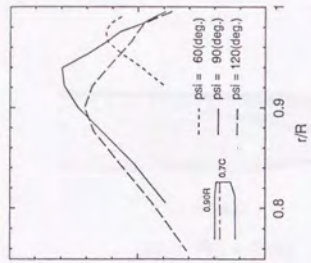
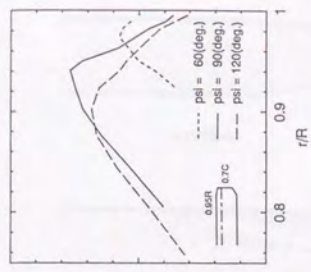


$\psi = 120$ (deg.)

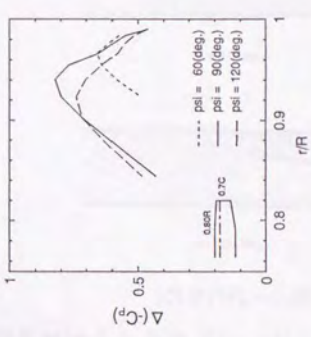
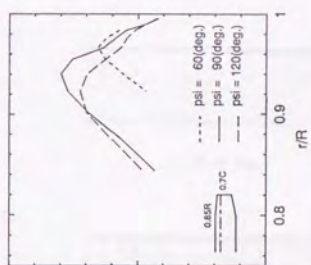
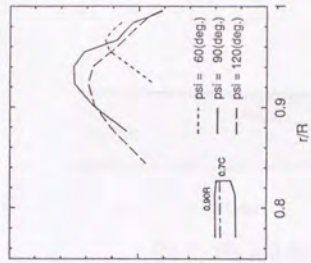
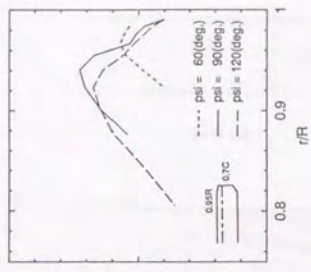
(c) $(r/R)_0 = 0.90$

(d) $(r/R)_0 = 0.95$

Fig. 3.39 翼端に逆テーパを付けたときのブレード
翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)

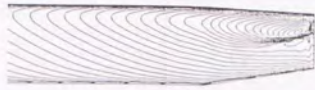


(a) $M_T = 0.6, \mu = 0.52$ [ケース (a)]

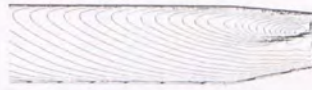


(b) $M_T = 0.7, \mu = 0.3$ [ケース (b)]

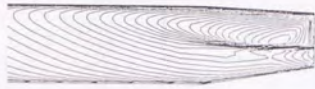
Fig. 3.40 翼端に順テーパを付けたときの $\Delta(-C_p)$



$\psi = 60$ (deg.)



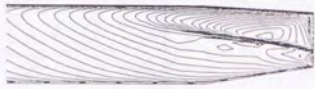
$\psi = 60$ (deg.)



$\psi = 90$ (deg.)

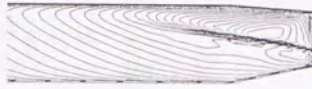


$\psi = 90$ (deg.)



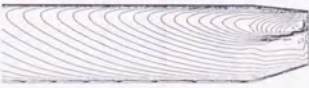
$\psi = 120$ (deg.)

(a) $(r/R)_0 = 0.80$

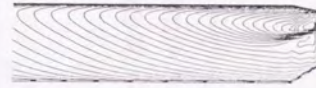


$\psi = 120$ (deg.)

(b) $(r/R)_0 = 0.85$



$\psi = 60$ (deg.)



$\psi = 60$ (deg.)



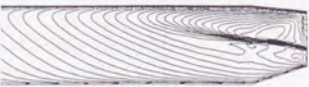
$\psi = 90$ (deg.)

(c) $(r/R)_0 = 0.90$

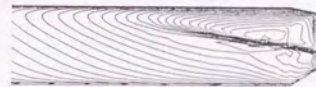


$\psi = 90$ (deg.)

(d) $(r/R)_0 = 0.95$



$\psi = 120$ (deg.)



$\psi = 120$ (deg.)

Fig. 3.41 翼端に順テーパを付けたときのブレード
翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)

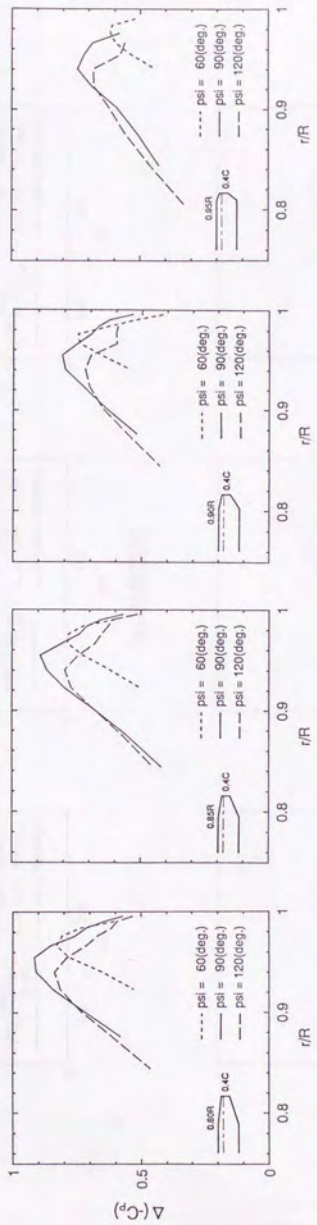
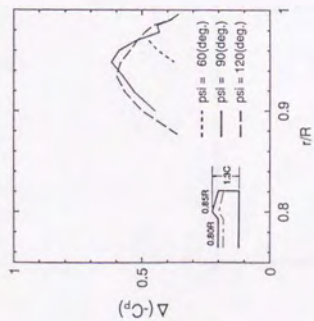
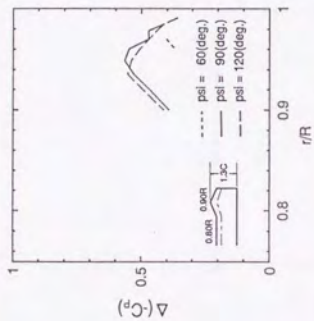
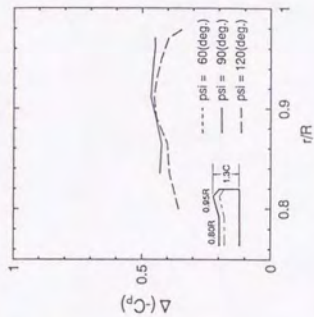
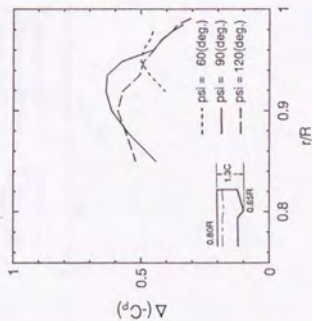
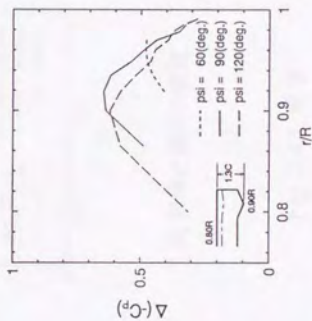
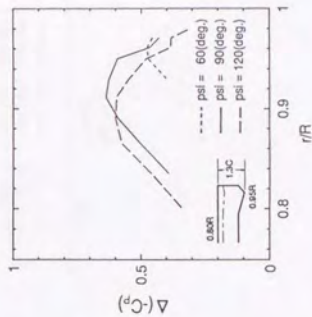


Fig. 3.42 翼端にテーパ比の小さなテーパを付けたときの $\Delta(-C_p)$
 ($M_T = 0.7, \mu = 0.3$)



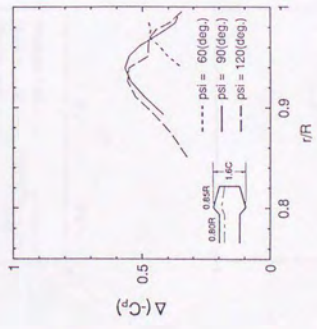
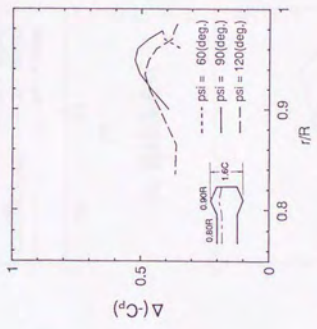
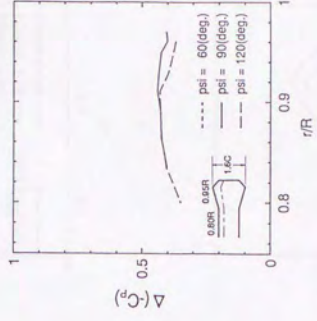
(a) 前縁突起



(b) 後縁突起

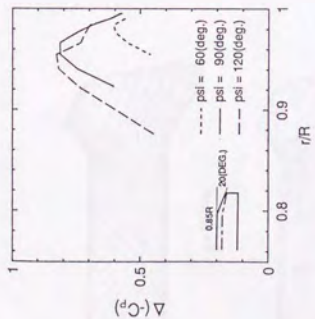
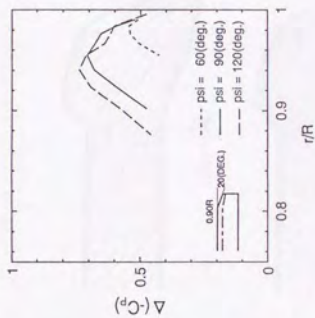
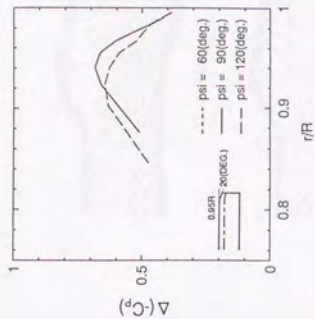
Fig. 3.43 翼端の前縁、後縁に突起を付けたときの $\Delta(-C_p)$

($M_T = 0.7, \mu = 0.3$)

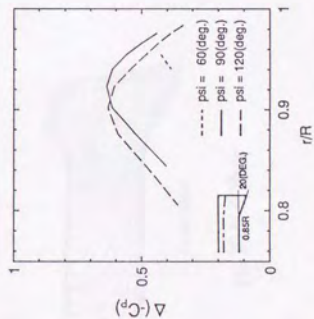
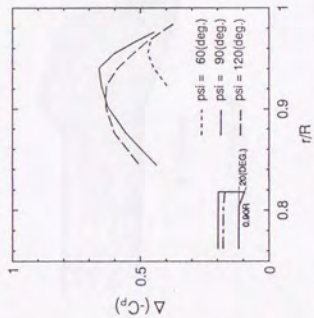
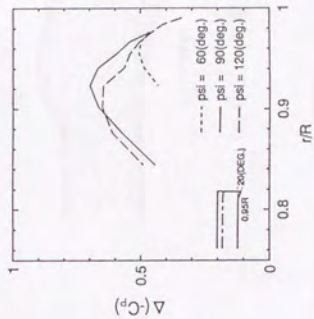


(c) 前縁と後縁の突起

Fig. 3.43 続き



(a) 前縁後退角



(b) 後縁後退角

Fig. 3.44 翼端の前縁、後縁に後退角を付けたときの $\Delta(-C_p)$

($M_T = 0.7, \mu = 0.3$)

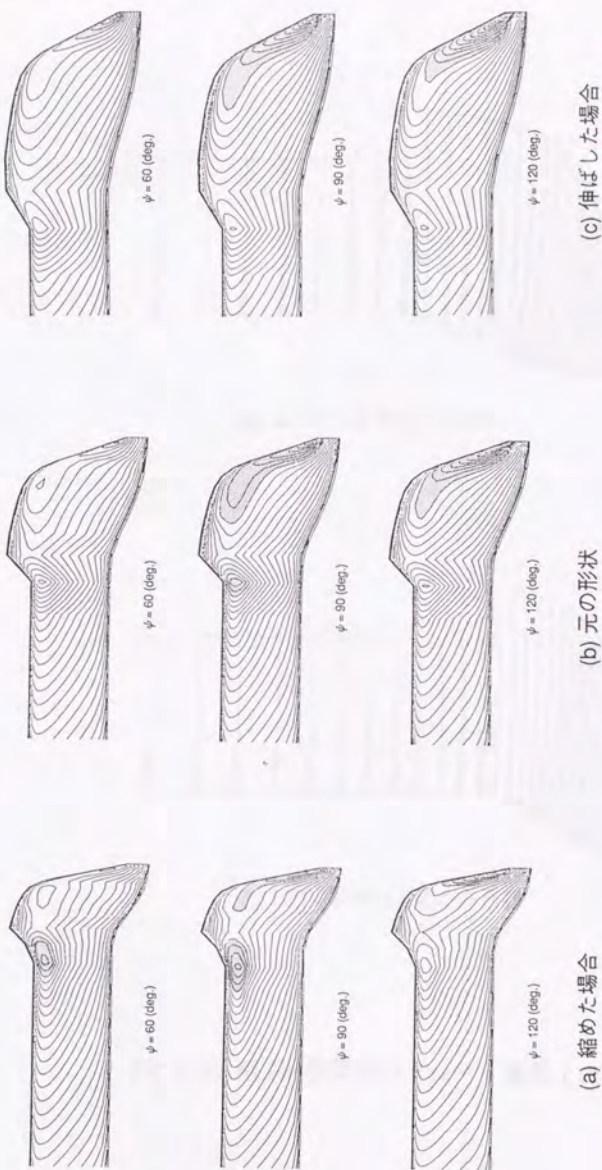
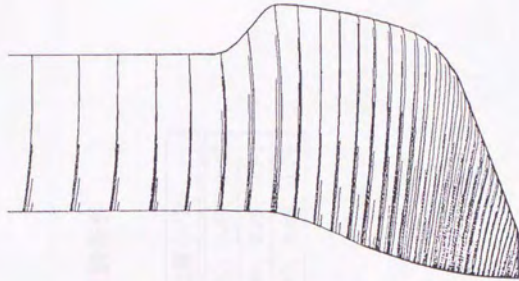
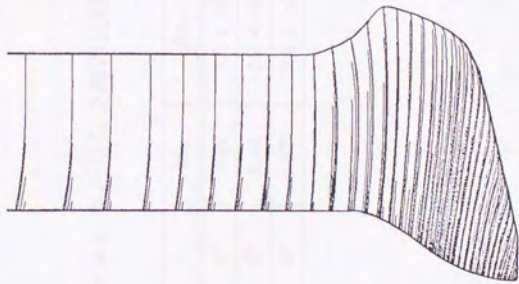


Fig. 3.45 BERP状翼端に変更を加えた場合のブレード翼面上等マッハ線図 ($M_T = 0.7$, $\mu = 0.3$)



(a) BERP状翼端の元の形状

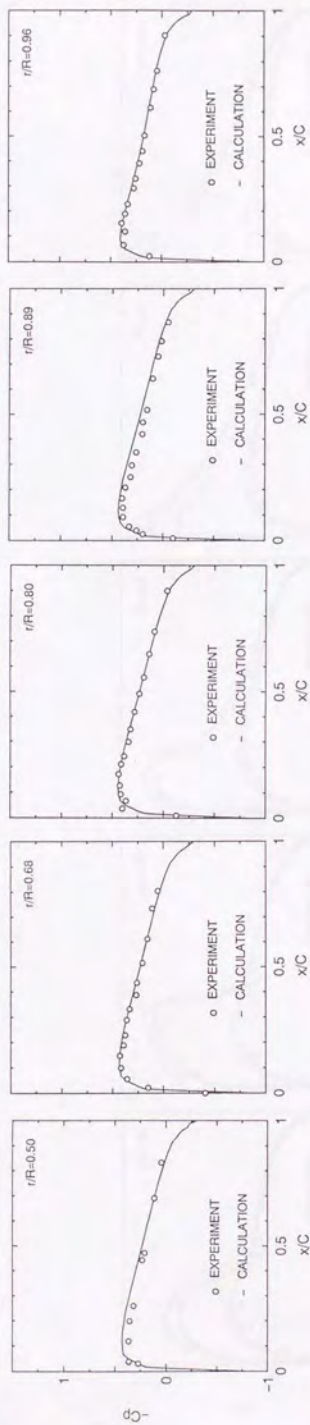


(b) BERP状翼端を縮めた形状

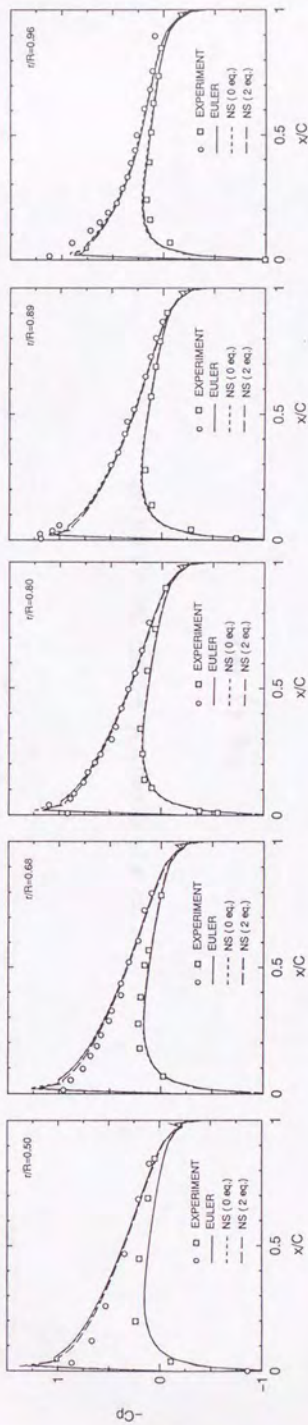
Fig. 3.46 BERP状翼端のブレード翼面上流線

Table 4.1 ホバリング時の比較に用いた実験の実験条件

ケース	θ_c	M_T	Re_C	圧力計測位置 (r/R)
(a)	0°	0.52	2.3×10^6	0.50, 0.68, 0.80, 0.89, 0.96
(b)	8°	0.44	2.0×10^6	0.50, 0.68, 0.80, 0.89, 0.96
(c)	8°	0.877	3.9×10^6	0.50, 0.68, 0.80, 0.89, 0.96

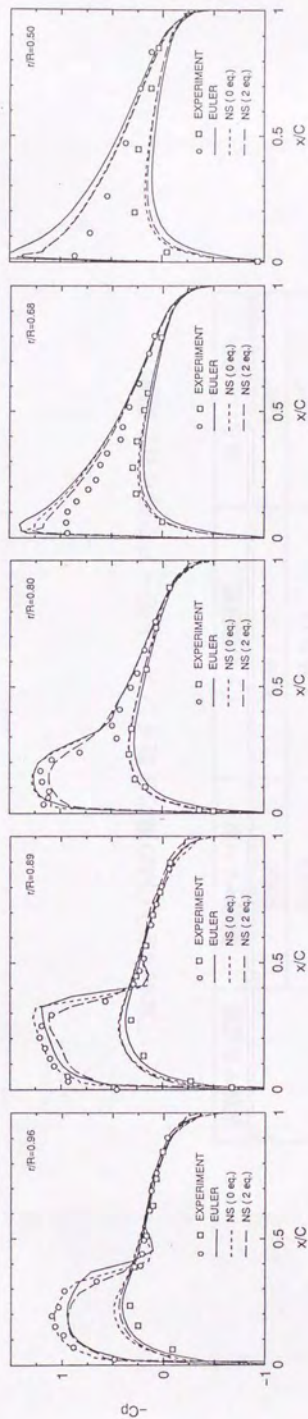


(a) $\theta_c = 0$ (deg.), $M_T = 0.52$, $Re_c = 2.3 \times 10^6$



(b) $\theta_c = 8$ (deg.), $M_T = 0.44$, $Re_c = 2.0 \times 10^6$

Fig. 4.1 ホバリング時の計算結果と実験値との比較

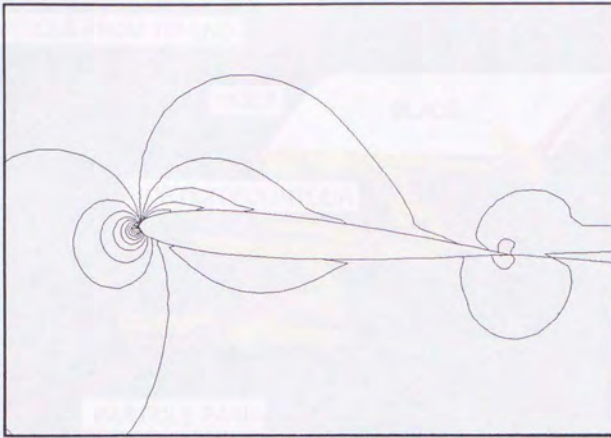


(c) $\theta_c = 8$ (deg.), $M_t = 0.877$, $Re_c = 3.9 \times 10^6$

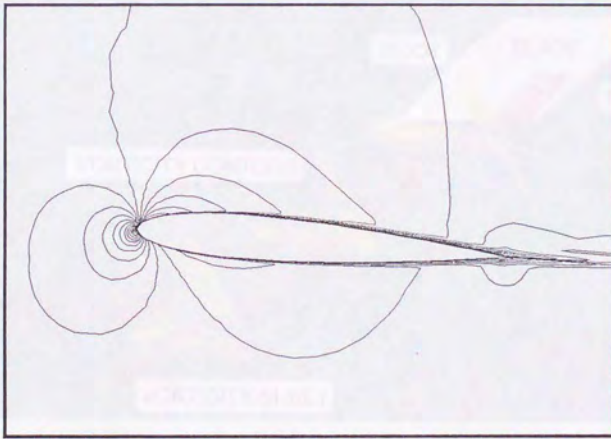
Fig. 4.1 続き

Table 4.2 LCMの推力係数インプットモードで得られた迎角

実験での迎角	翼端マッハ数	C_T の実験値	得られた迎角
8°	0.439	4.59×10^{-3}	6.05°
	0.612	4.55×10^{-3}	6.66°
	0.794	4.62×10^{-3}	6.87°
	0.877	4.73×10^{-3}	7.05°



(a) オイラー



(b) NS

Fig. 4.2 翼端付近の2次元断面における等マッハ線図
 ($\theta_c = 8$ (deg.), $M_T = 0.44$, $Re_c = 2.0 \times 10^6$)

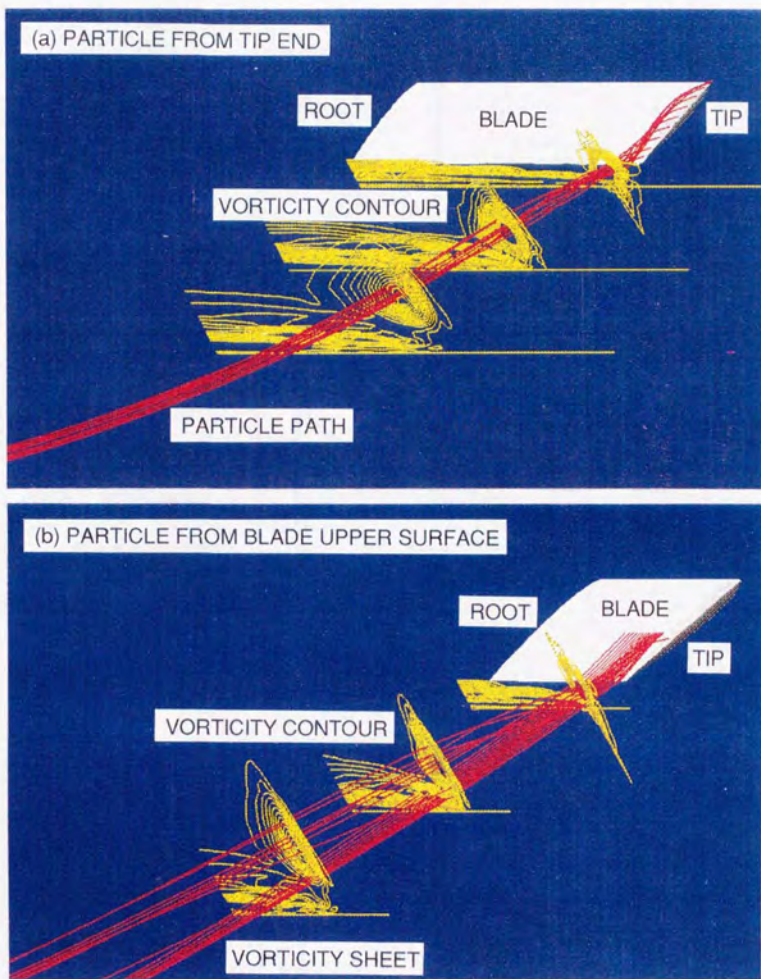
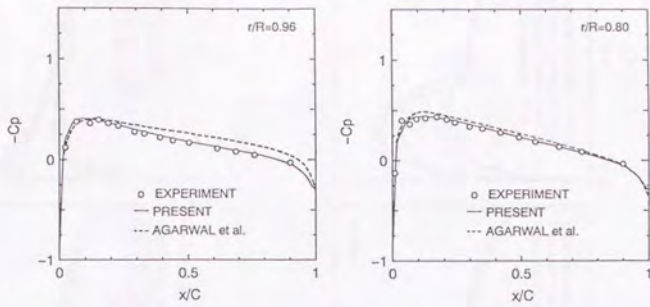
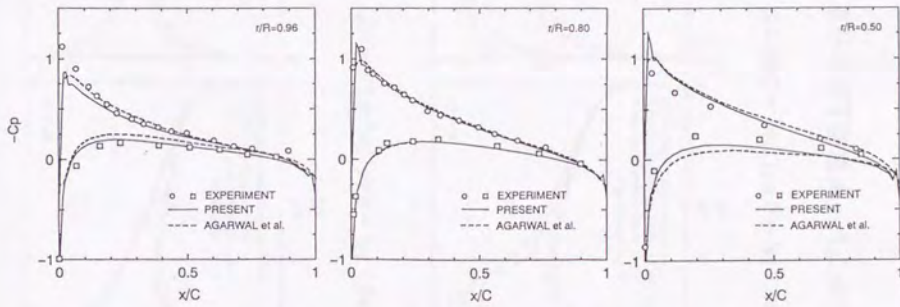


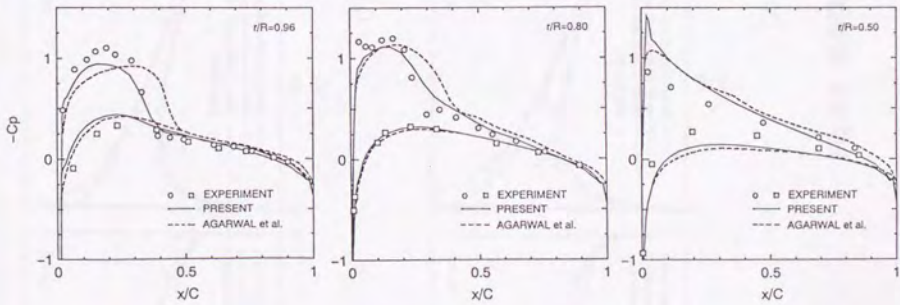
Fig. 4.3 後流の可視化 ($\theta_0 = 14$ (deg.), $M_T = 0.44$, $Re_c = 2.0 \times 10^6$)



(a) $\theta_c = 0$ (deg.), $M_T = 0.52$, $Re_c = 2.3 \times 10^6$



(b) $\theta_c = 8$ (deg.), $M_T = 0.44$, $Re_c = 2.0 \times 10^6$



(c) $\theta_c = 8$ (deg.), $M_T = 0.877$, $Re_c = 3.9 \times 10^6$

Fig. 4.4 他の解析法との比較

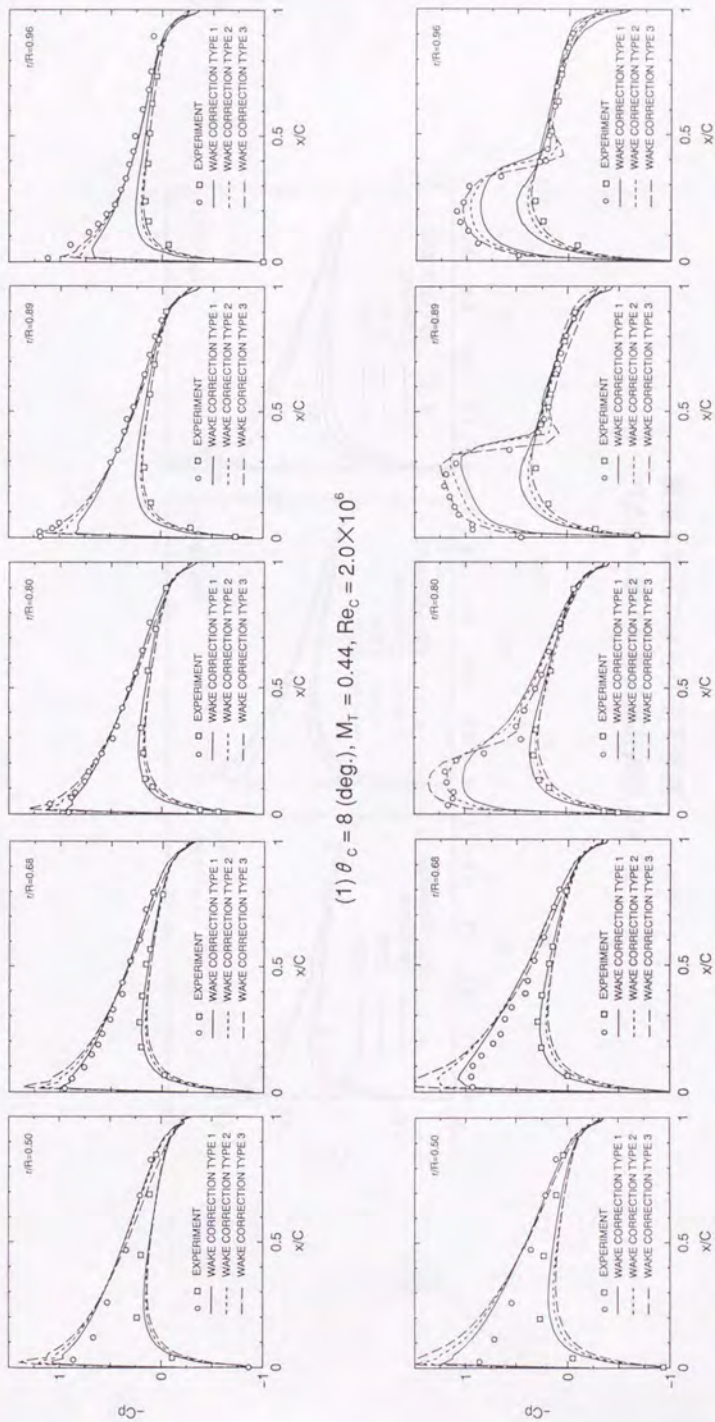


Fig. 4.5 境界条件の扱いがブレード翼面上圧力分布に及ぼす影響

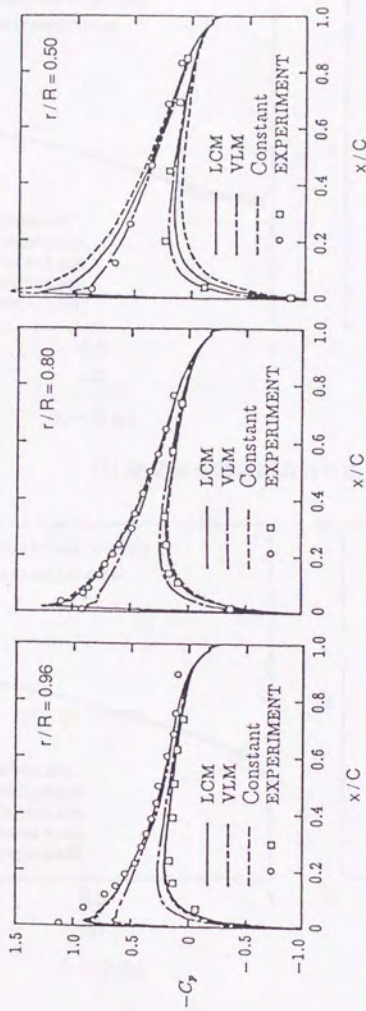
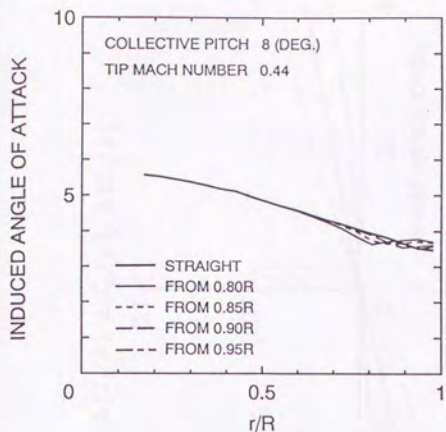
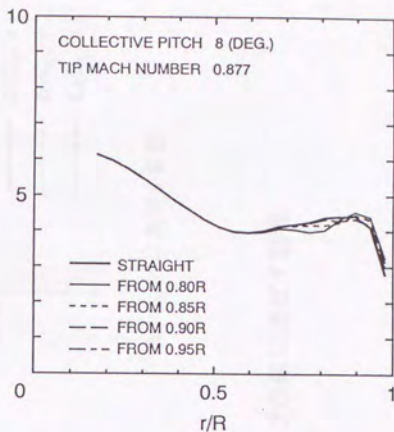


Fig. 4.6 誘導速度計算法の違いがブレード翼面上圧力分布に及ぼす影響

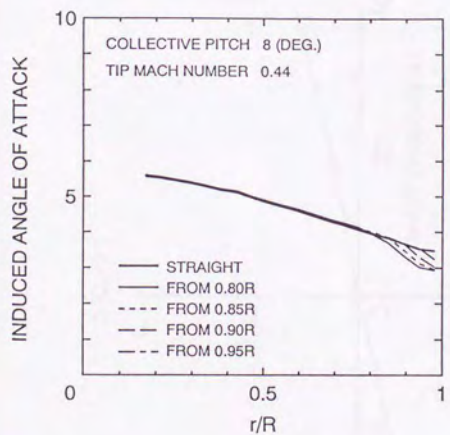


ケース(b)

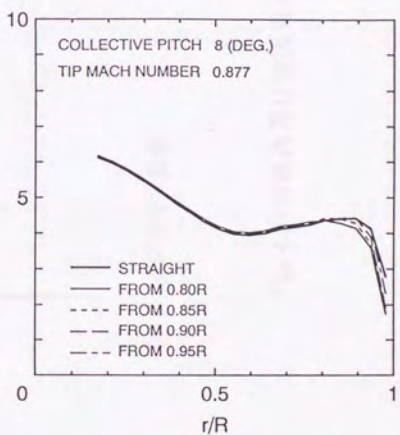


ケース(c)

(1) 後退角が誘導迎角分布に及ぼす影響



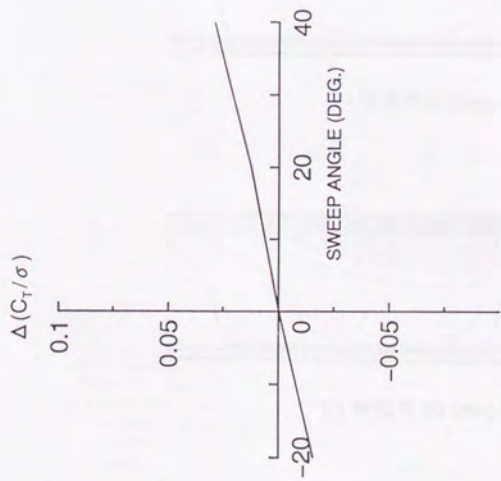
ケース(b)



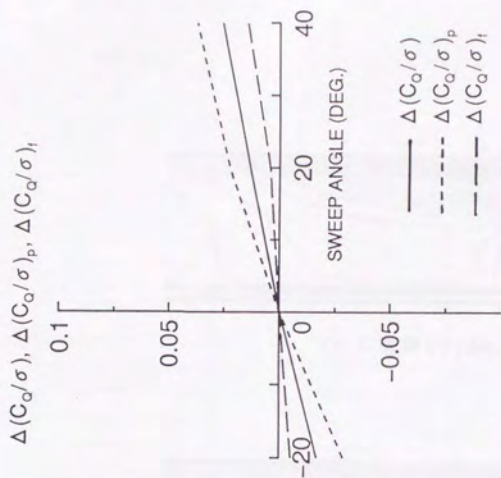
ケース(c)

(2) テーバが誘導迎角分布に及ぼす影響

Fig. 4.7 LCMで計算した誘導迎角分布

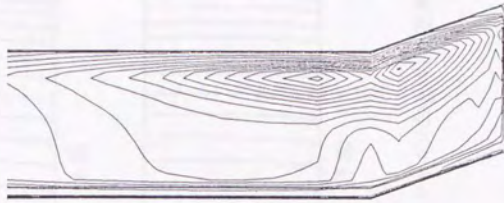


(a) C_T/σ に及ぼす影響

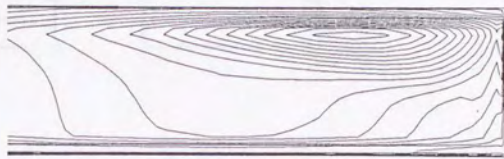


(b) C_D/σ に及ぼす影響

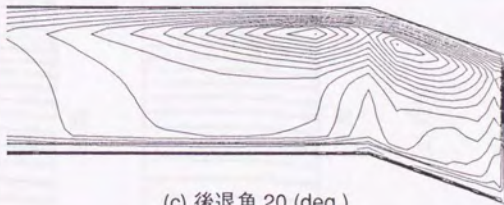
Fig. 4.8 前進角及び後退角がホバリング性能に及ぼす影響



(a) 前進角 20 (deg.)

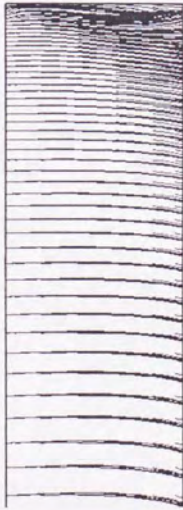


(b) 後退角 0 (deg.)

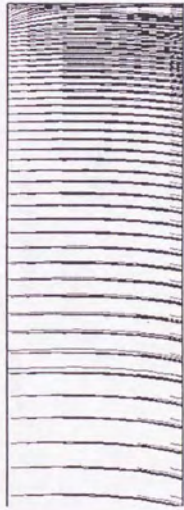


(c) 後退角 20 (deg.)

Fig. 4.9 前進角及び後退角を付けたときの等摩擦力線図

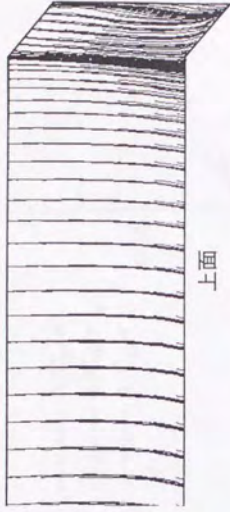


上面

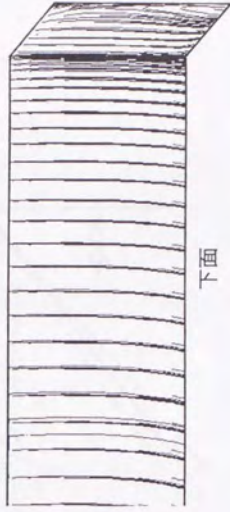


下面

(a) 矩形



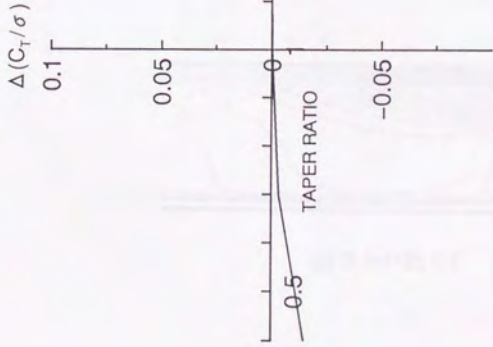
上面



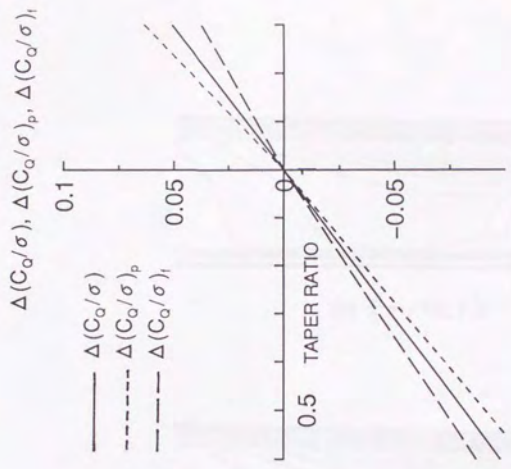
下面

(b) 0.95Rから40(deg.)の後退角

Fig. 4.10 ケース(b)のブレード翼面上流線

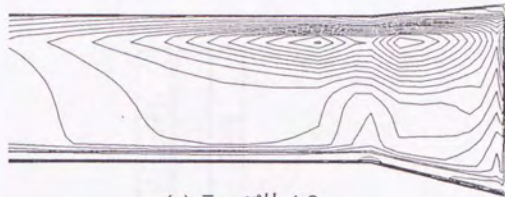


(a) C_T/σ に及ぼす影響



(b) C_O/σ に及ぼす影響

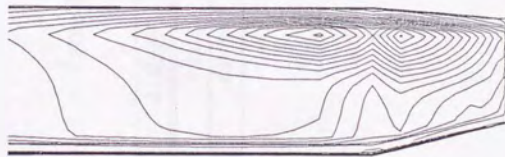
Fig. 4.11 テーパーがホバリング性能に及ぼす影響



(a) テーパー比 1.3



(b) テーパー比 1.0



(c) テーパー比 0.7

Fig. 4.12 逆テーパー及び順テーパーを付けたときの等摩擦力線図

Table 4.3 先進的平面形のホバリング性能

	$\Delta(C_T/\sigma)$	$\Delta(C_Q/\sigma)$	$\Delta(C_Q/\sigma)_p$	$\Delta(C_Q/\sigma)_f$
BERP	-0.213	-0.182	-0.246	-0.118
PF2	-0.002	-0.033	-0.044	-0.022

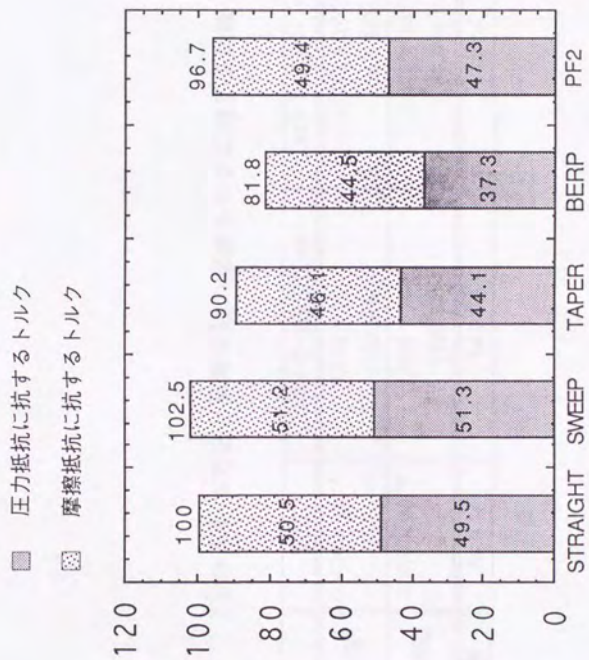
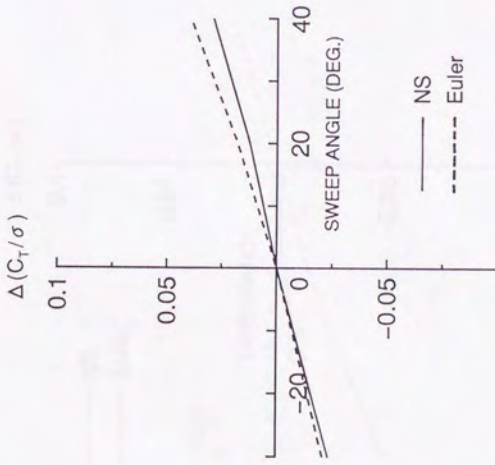


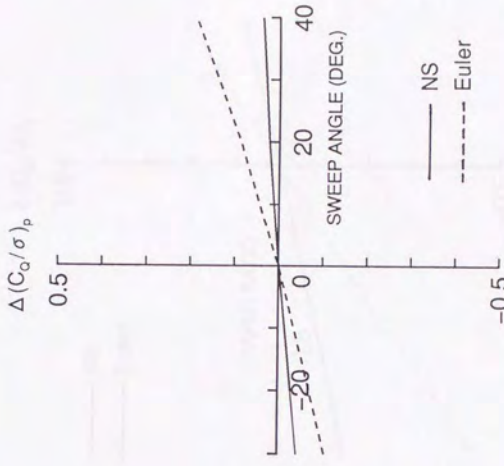
Fig. 4.13 圧力抵抗に抗するトルクと摩擦抵抗に抗するトルクの割合

Table 4.4 本方法と翼素理論の摩擦トルクに対する比較

	矩形	0.85R から後退角 40°	0.85R からテーパー比 0.4
本方法	1.056×10^{-4}	1.071×10^{-4} (101.5 %)	0.913×10^{-4} (86.5 %)
翼素理論	1.656×10^{-4}	1.656×10^{-4} (100 %)	1.400×10^{-4} (84.5 %)
誤差	56.9 %	54.6 %	53.3 %

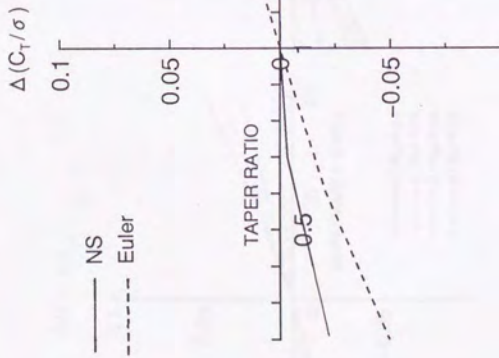


(a) C_T/σ に及ぼす影響

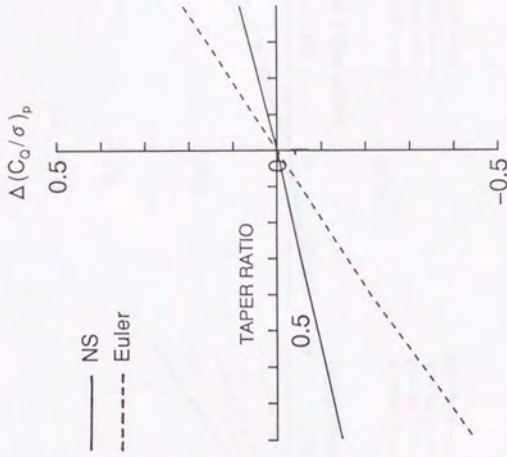


(b) C_D/σ に及ぼす影響

Fig. 4.14 前進角及び後退角がホバリング性能に及ぼす影響
(NSとオイラーの比較)

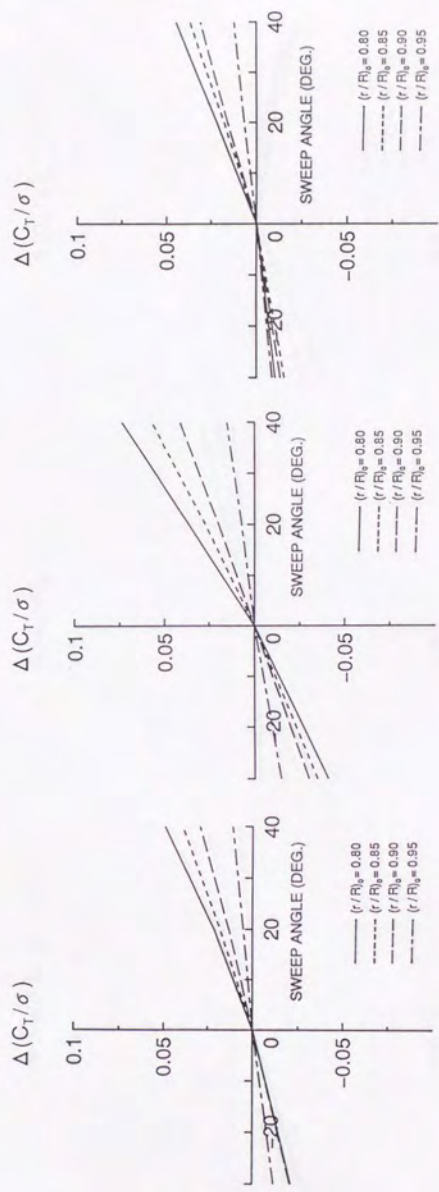


(a) C_T/σ に及ぼす影響



(b) C_O/σ に及ぼす影響

Fig. 4.15 テーパーがホバリング性能に及ぼす影響
(NSとオイラーの比較)



(a) $M_T = 0.44$

(b) $M_T = 0.794$

(c) $M_T = 0.877$

Fig. 4.16 前進角及び後退角が C_T/σ に及ぼす影響
(オイラーによるパラメトリックスタディ)

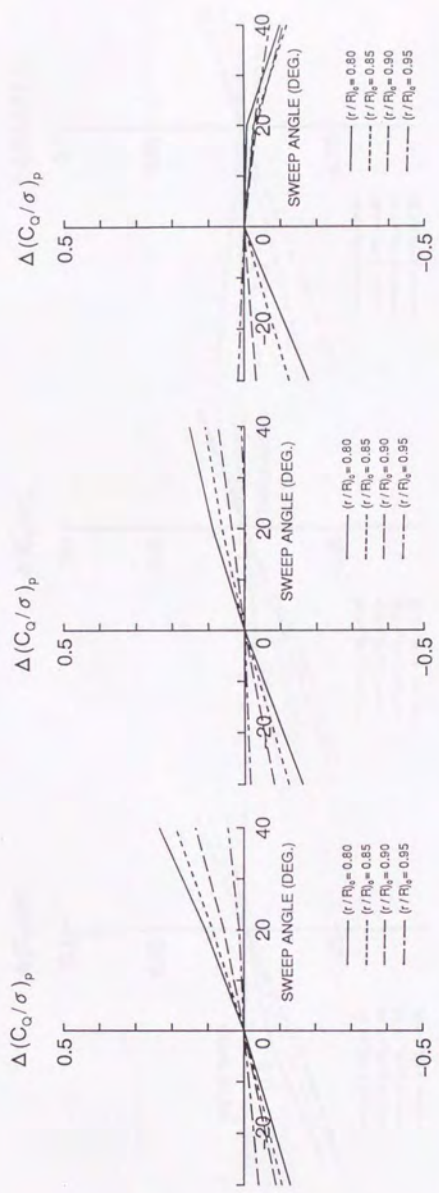
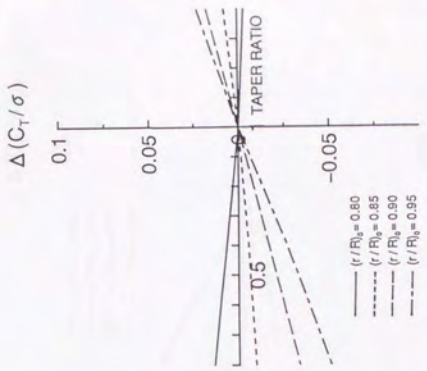
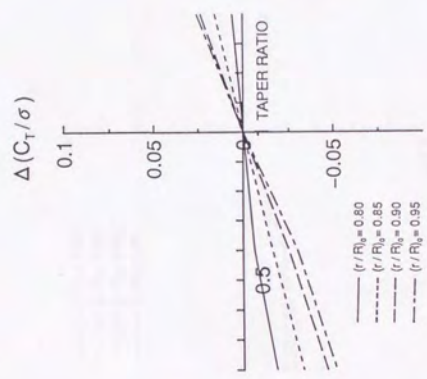


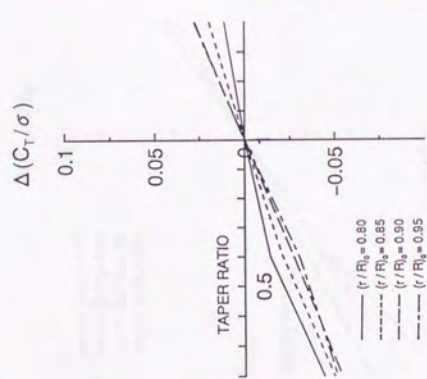
Fig. 4.17 前進角及び後退角が $(C_D/\sigma)_p$ に及ぼす影響
 (オイラーによるパラメトリックスタディ)



(a) $M_T = 0.44$



(b) $M_T = 0.794$



(c) $M_T = 0.877$

Fig. 4.18 テーパーが C_T/σ に及ぼす影響
(オイラーによるパラメトリックスタディ)

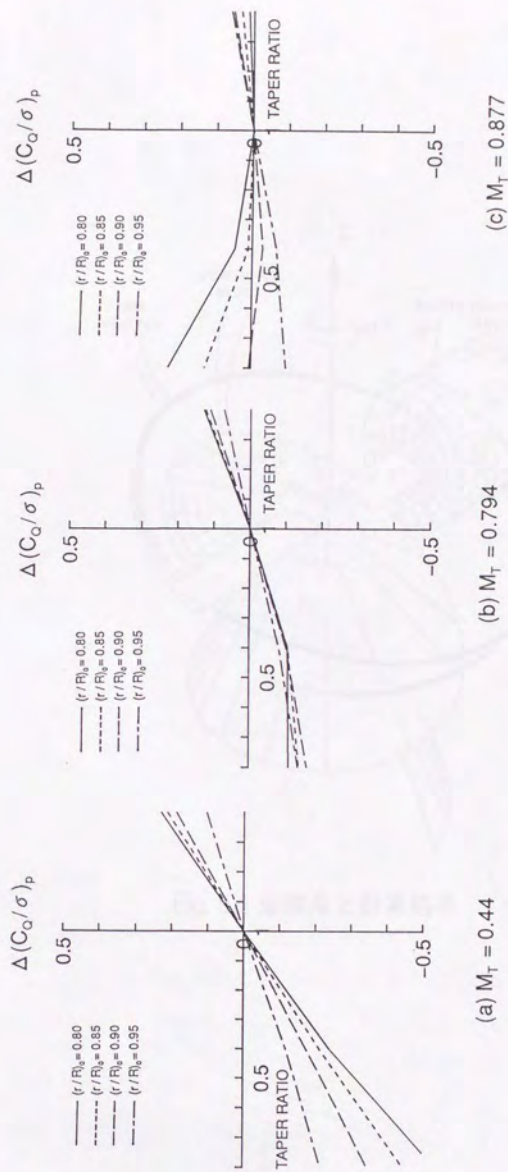


Fig. 4.19 テーパーが $(C\sigma/\sigma)_p$ に及ぼす影響
 (オイラーによるパラメトリックスタディ)

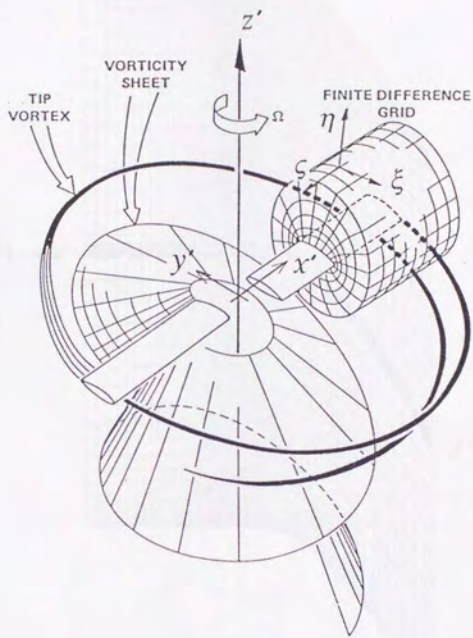


Fig. 5.1 座標系と計算格子

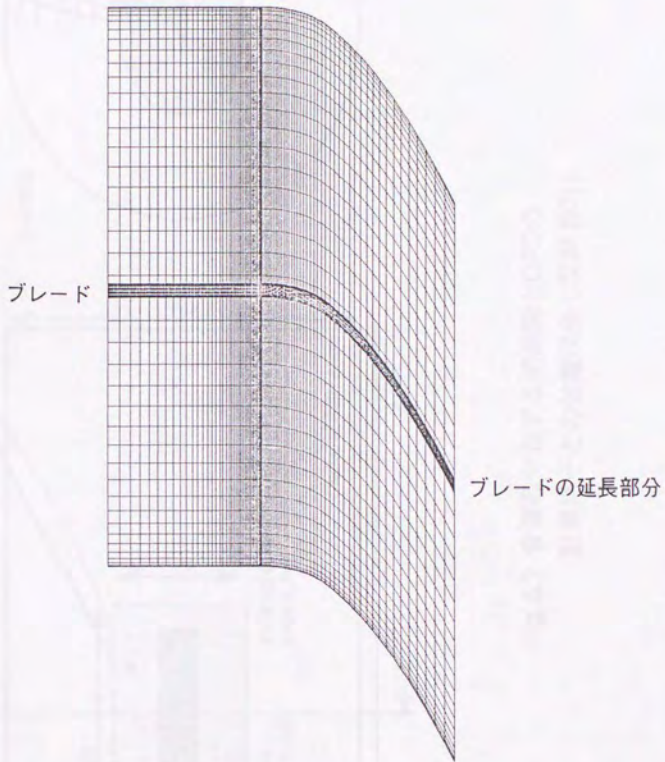


Fig. 5.2 Z軸方向から見た計算格子

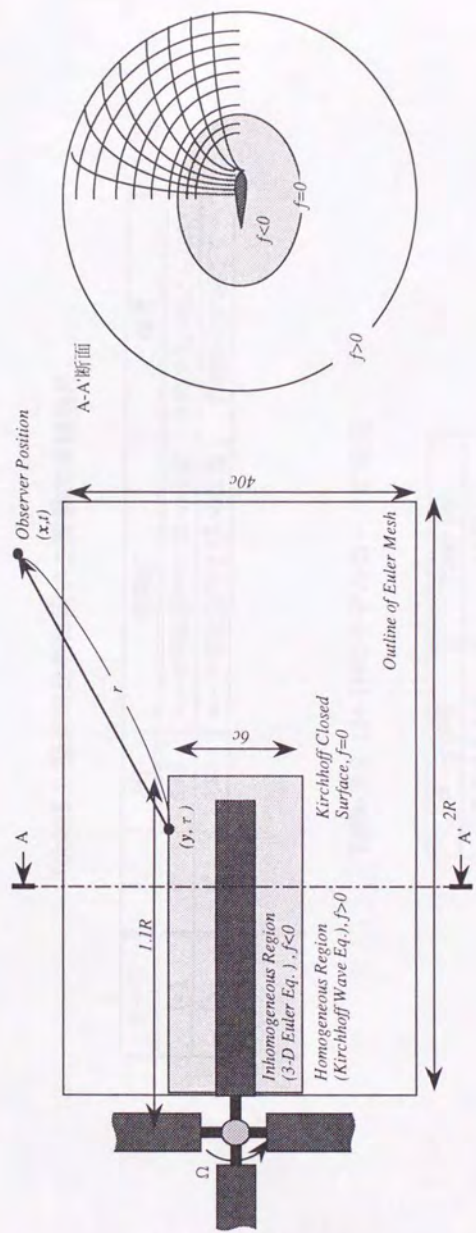


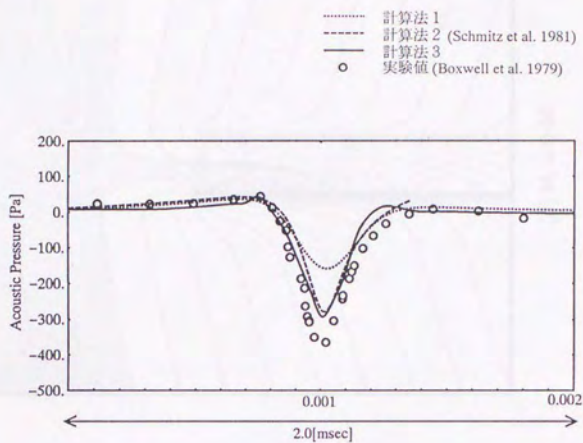
Fig. 5.3 音源の分布する閉曲面とCFDの計算格子との位置関係 (文献 [97])

Table 5.1 騒音の比較に用いた実験の実験条件

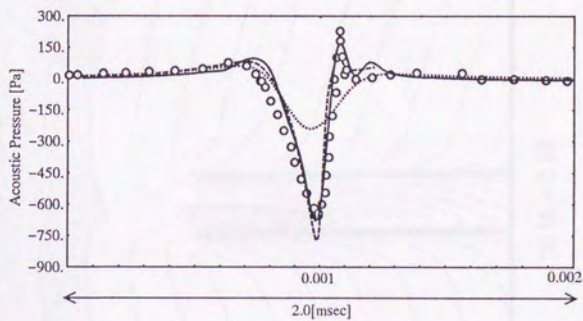
ケース	θ_c	M_T	観測点	備考
(a)	0°	0.88	ロータ回転面内で3Rの位置	非局所化が起らない
(b)	0°	0.90	ロータ回転面内で3Rの位置	非局所化が起る

Table 5.2 UH-1Hのモデルロータの諸元

ロータ半径	1.045 [m]
アスペクト比	13.71
翼型	NACA0012
ブレード枚数	4

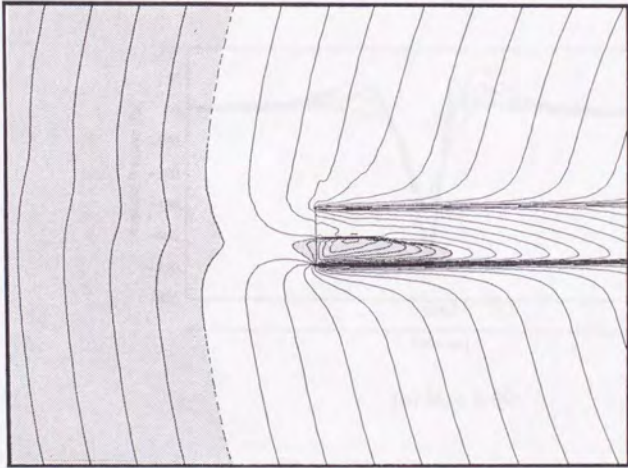


(a) $M_T = 0.88$

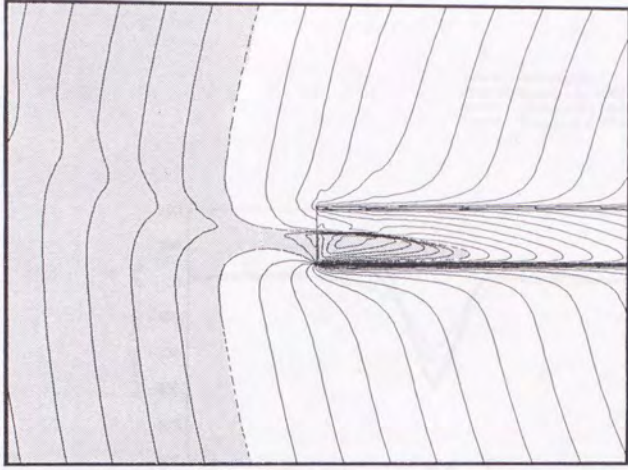


(b) $M_T = 0.90$

Fig. 5.4 実験値との比較

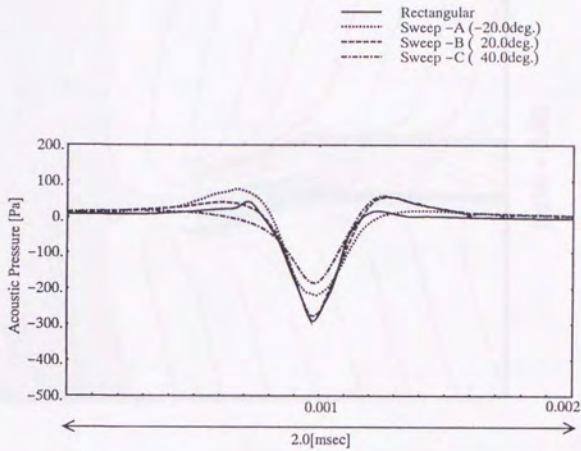


(a) $M_T = 0.88$

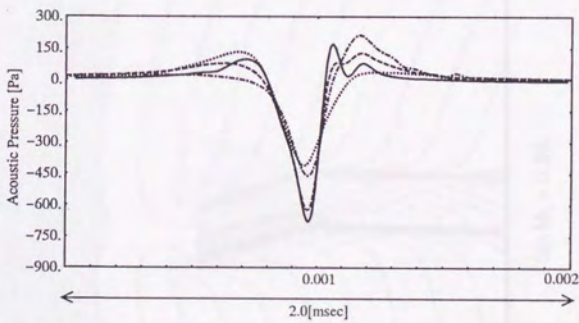


(b) $M_T = 0.90$

Fig. 5.5 矩形翼端のブレード周辺等マッハ線図 超音速領域

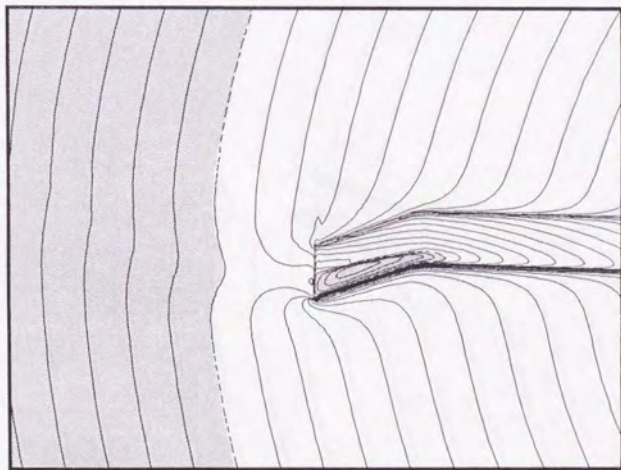


(a) $M_T = 0.88$

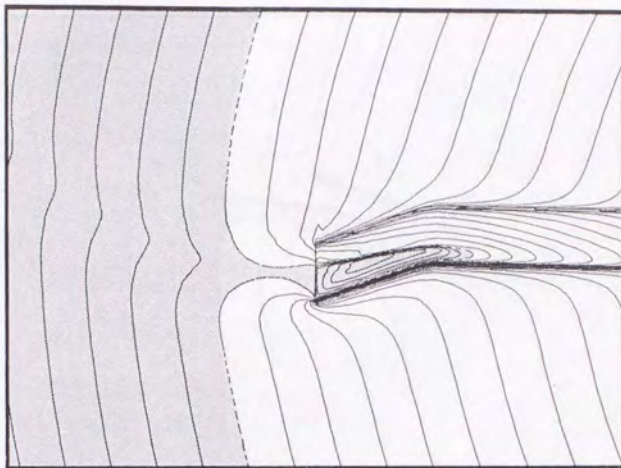


(b) $M_T = 0.90$

Fig. 5.6 後退角が音圧に及ぼす影響



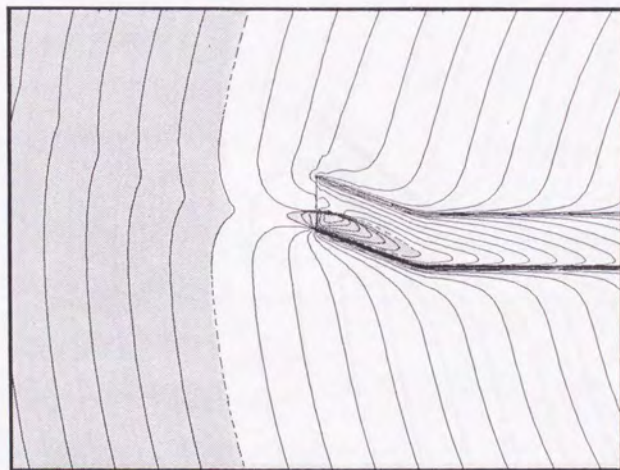
(a) $M_T = 0.88$



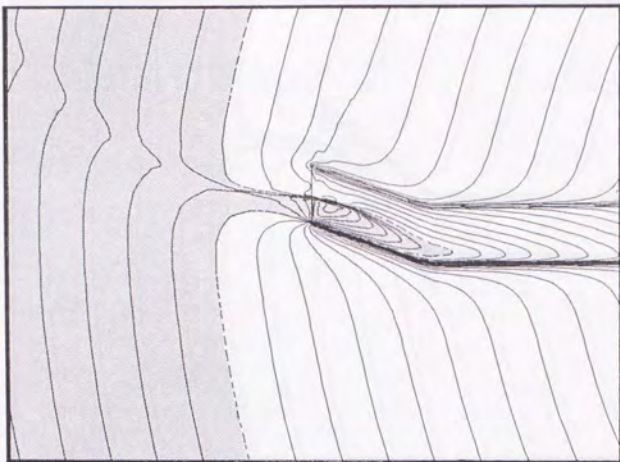
(b) $M_T = 0.90$

Fig. 5.7 (1) 前進角 20 (deg.) を付けたときの
ブレード周辺等マッハ線図

☐ 超音速領域



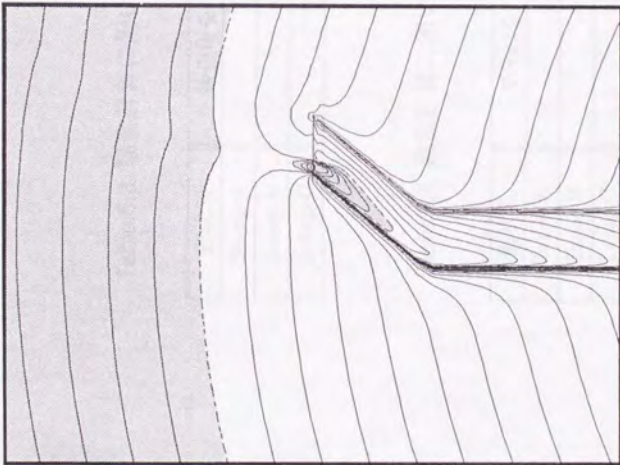
(a) $M_T = 0.88$



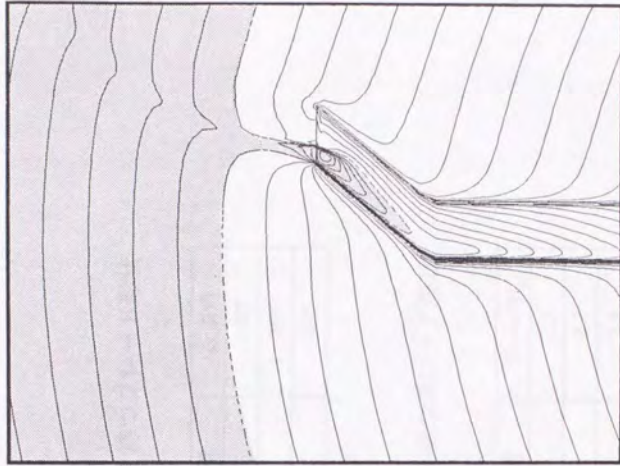
(b) $M_T = 0.90$

Fig. 5.7 (2) 後退角 20 (deg.) を付けたときの
ブレード周辺等マッハ線図

□ 超音速領域



(a) $M_T = 0.88$



(b) $M_T = 0.90$

Fig. 5.7 (3) 後退角 40 (deg.) を付けたときの
ブレード周辺等マッハ線図

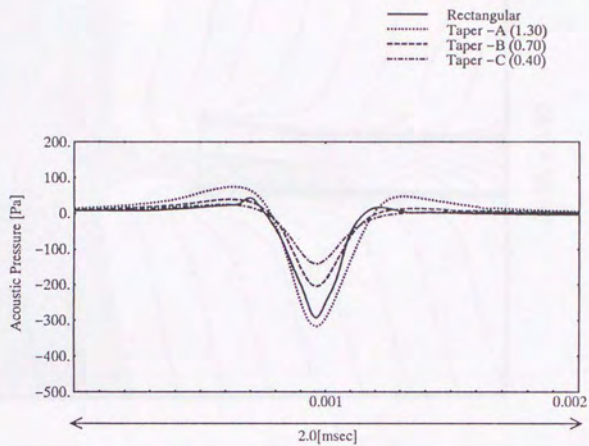
□ 超音速領域

Table 5.3 騒音計算に用いた後退角を持つブレード形状

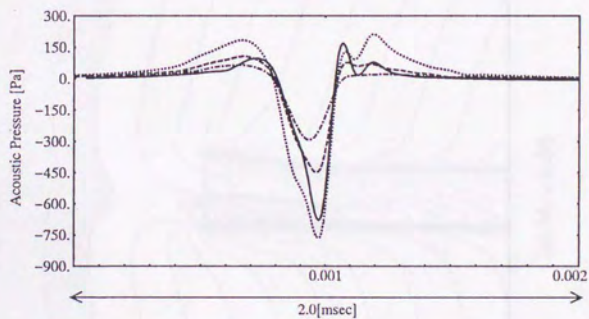
形状名	後退角を付け始める位置	後退角
Sweep-A	0.858R	-20°
Sweep-B	0.858R	20°
Sweep-C	0.858R	40°

Table 5.4 騒音計算に用いたテーパを持つブレード形状

形状名	テーパを付け始める位置	テーパ比
Taper-A	0.858R	1.3
Taper-B	0.858R	0.7
Taper-C	0.858R	0.4

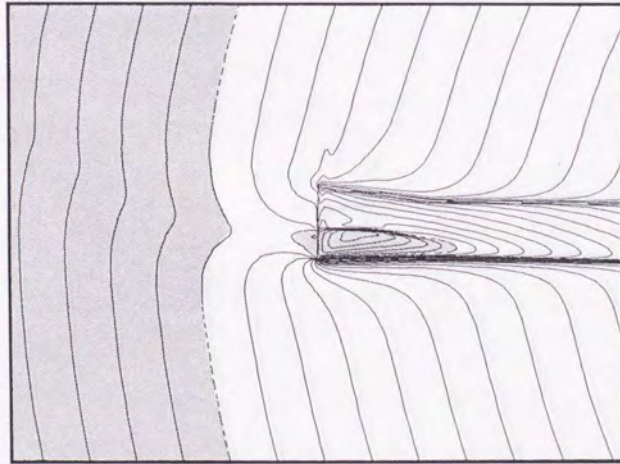


(a) $M_T = 0.88$

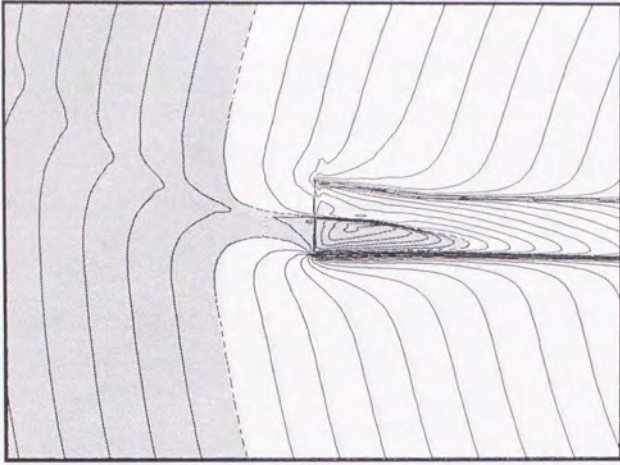


(b) $M_T = 0.90$

Fig. 5.8 テーパーが音圧に及ぼす影響

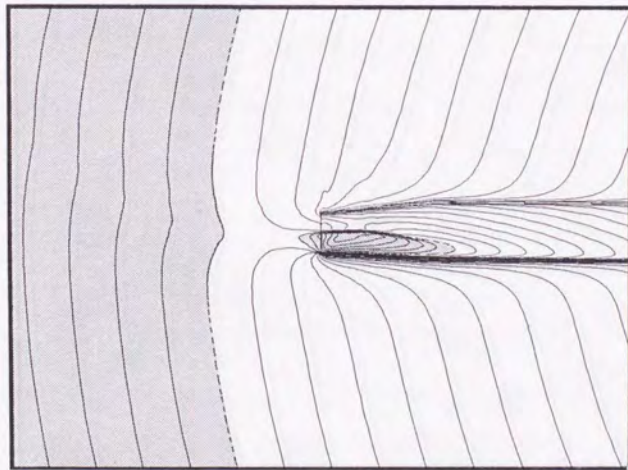


(a) $M_T = 0.88$

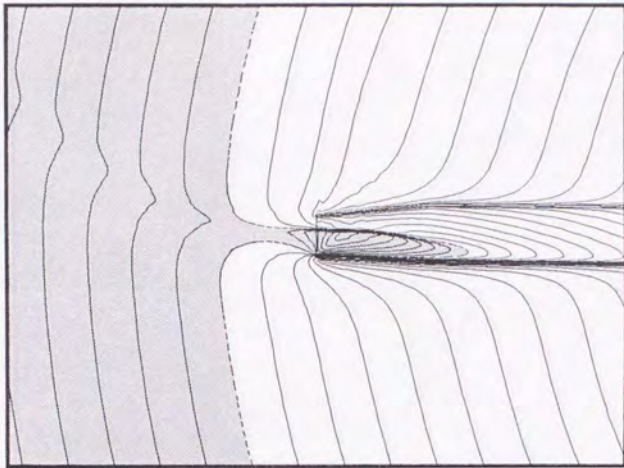


(b) $M_T = 0.90$

Fig. 5.9 (1) 逆テーパー (テーパー比1.3) を付けたときの
ブレード周辺等マッハ線図 超音速領域



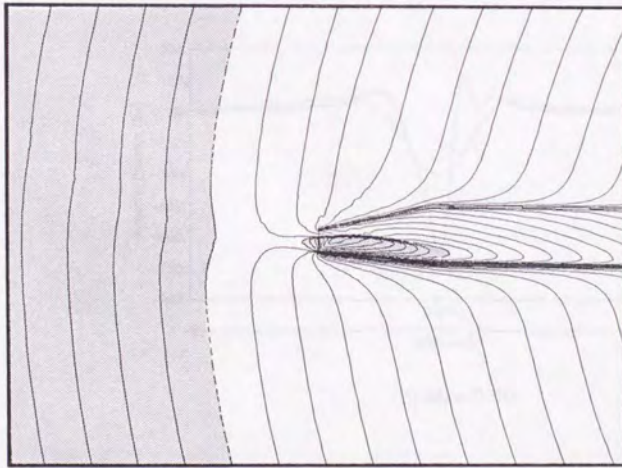
(a) $M_\infty = 0.88$



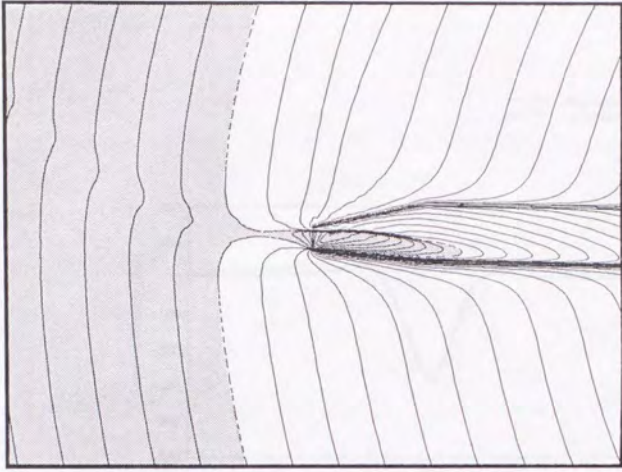
(b) $M_\infty = 0.90$

Fig. 5.9 (2) 順テーパー (テーパー比0.7) を付けたときの
ブレード周辺等マッハ線図

□ 超音速領域

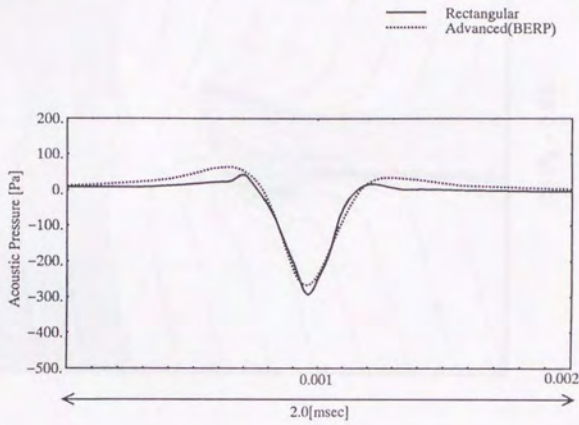


(a) $M_T = 0.88$

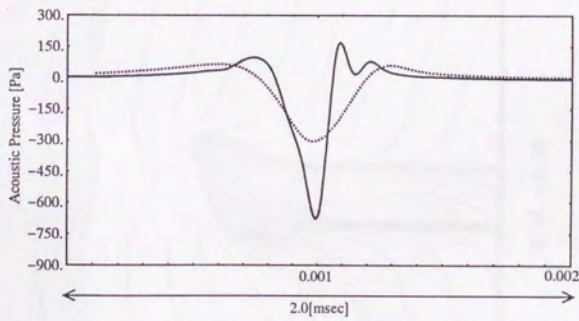


(b) $M_T = 0.90$

Fig. 5.9 (3) 順テーパーバ (テーパー比0.4) を付けたときの
ブレード周辺等マッハ線図 超音速領域



(a) $M_T = 0.88$



(b) $M_T = 0.90$

Fig. 5.10 BERP状翼端が音圧に及ぼす影響

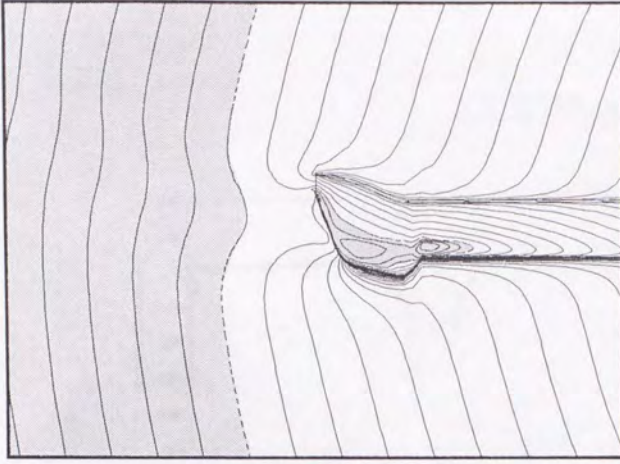
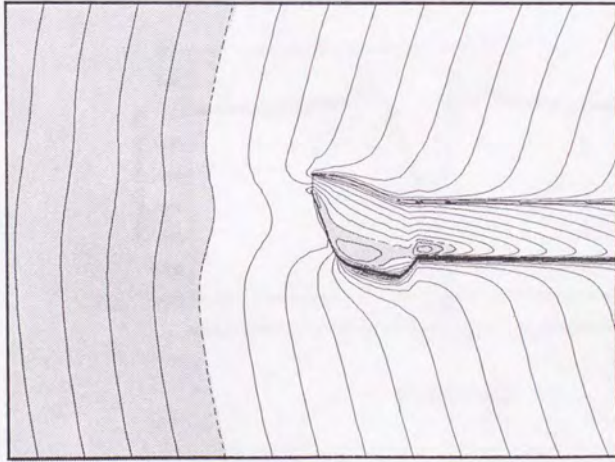
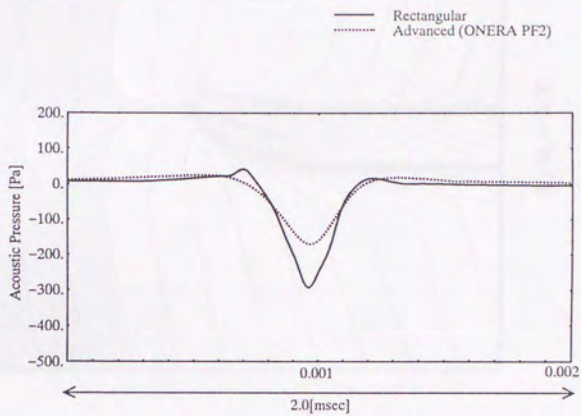
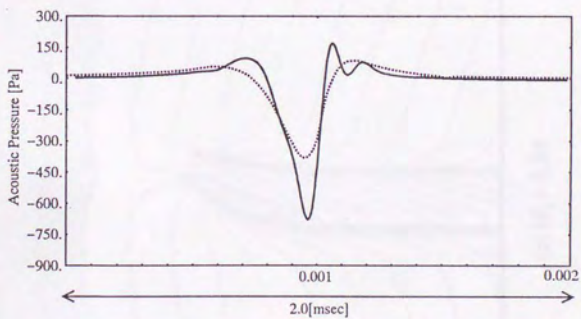


Fig. 5.11 BERP状翼端のブレード周辺等マッハ線図 超音速領域

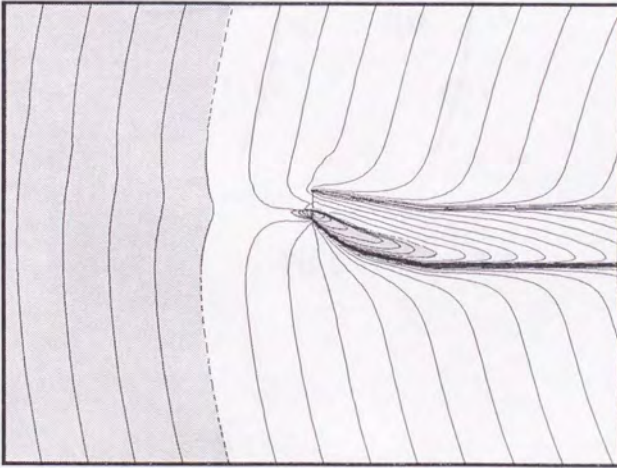


(a) $M_T = 0.88$

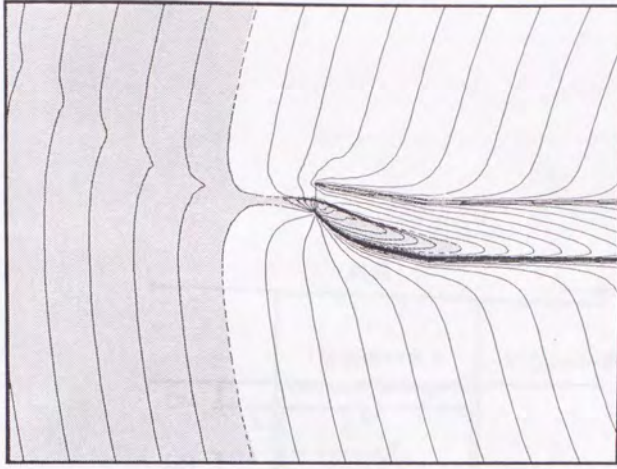


(b) $M_T = 0.90$

Fig. 5.12 PF2状翼端が音圧に及ぼす影響



(a) $M_t = 0.88$



(b) $M_t = 0.90$

Fig. 5.13 PF2状翼端のブレード周辺等マッハ線図 超音速領域

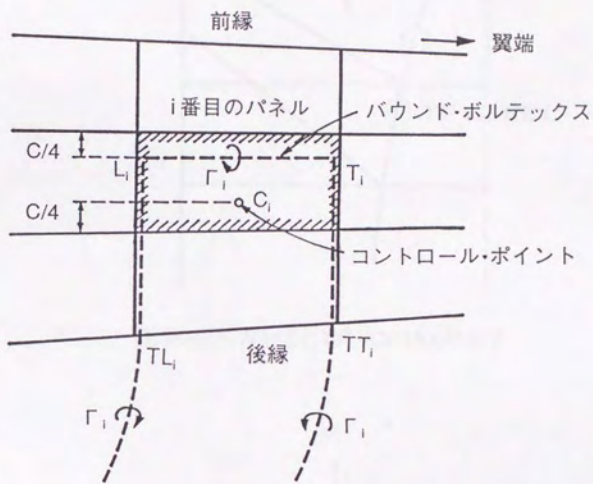
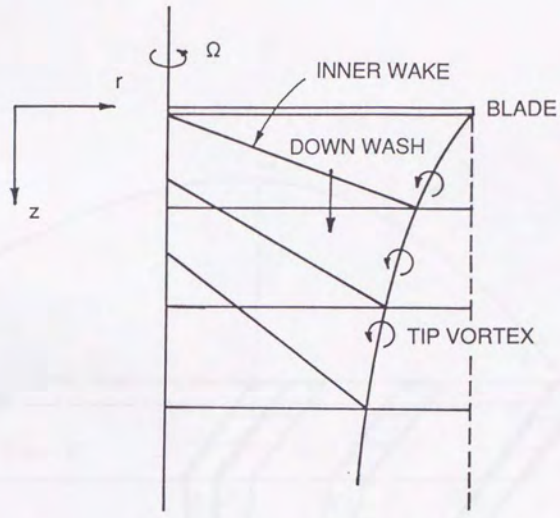
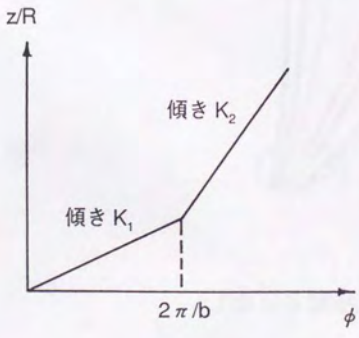


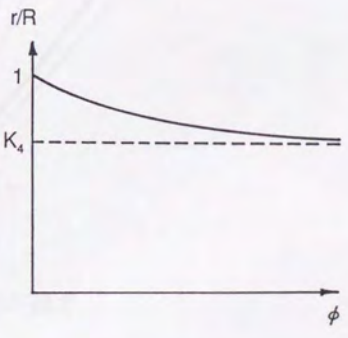
Fig. C.1 パネルの渦系



(a) INNER WAKEとTIP VORTEXの様子



(b) TIP VORTEXの落ちて行く様子



(c) 縮流の様子

Fig. C.2 K.B.H. Wake Model

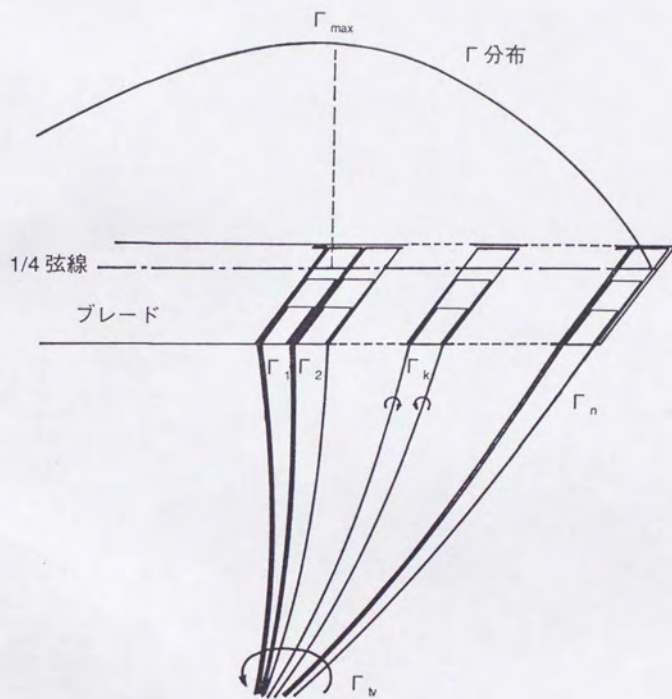


Fig. C.3 翼端渦の強さ

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