

STUDI NUMERIK TENTANG PENGENDALIAN SEPARASI ALIRAN DI DALAM CONICAL DIFFUSER MENGGUNAKAN CIRCULAR RING VORTEX GENERATOR

Oleh :

Chairunnisa

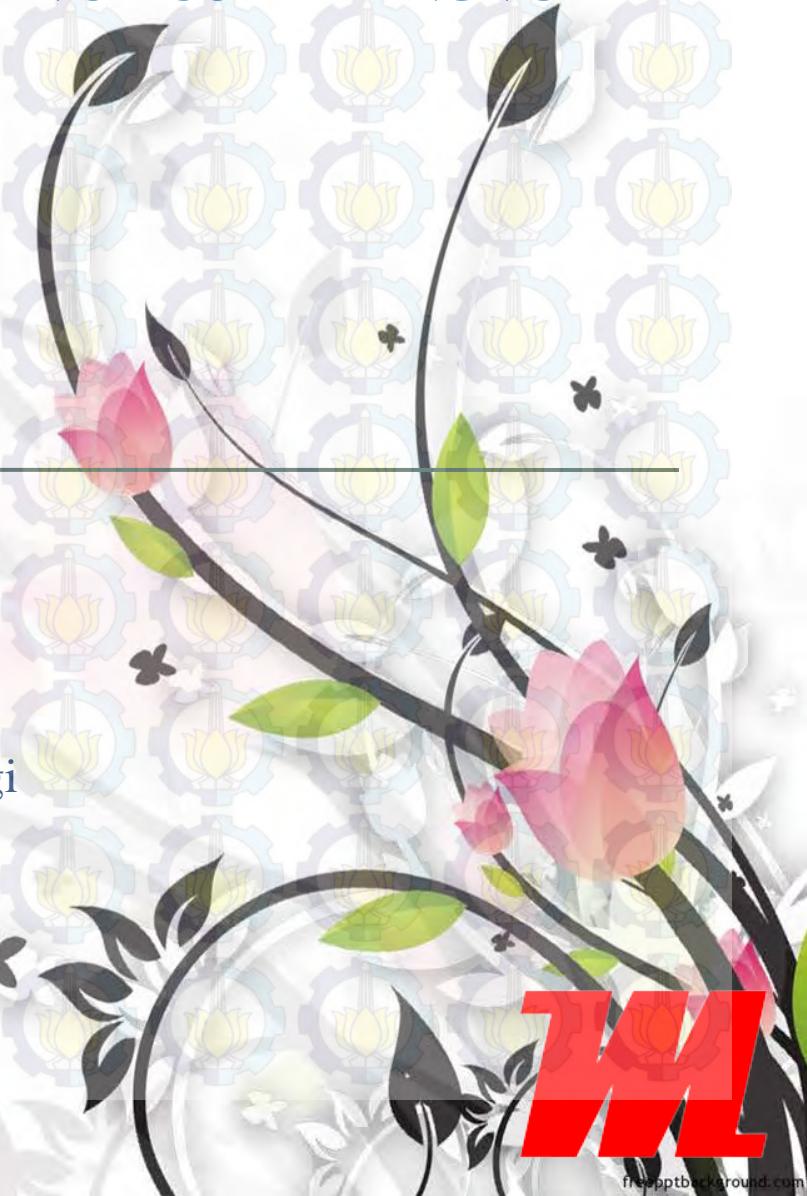
2113.202.012

Pembimbing :

Prof. Ir. Sutardi, M.Eng., Ph.D

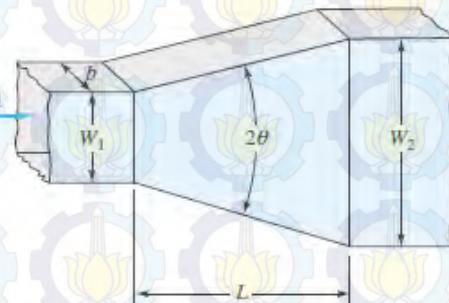
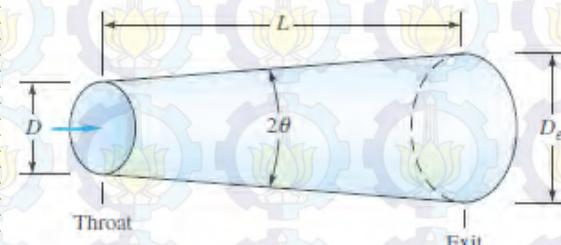
Program Magister
Bidang Keahlian Rekayasa Konversi Energi

Jurusan Teknik Mesin
Fakultas Teknologi Industri
Institut Teknologi Sepuluh Nopember
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Latar Belakang

Diffuser



Geometri tertentu

Performa

Modifikasi



Rumusan Masalah

- Sudut divergensi
 - Area ratio



Geometri
Diffuser



Momentum
aliran

Effect friction

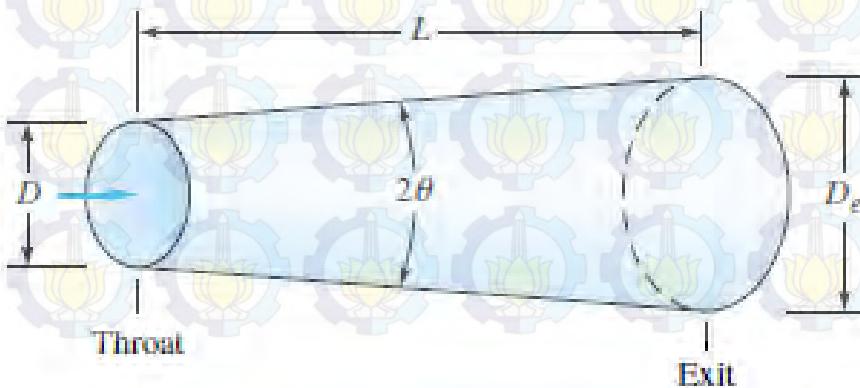
Adverse
pressure
gradient

Kontrol
Separasi : VG

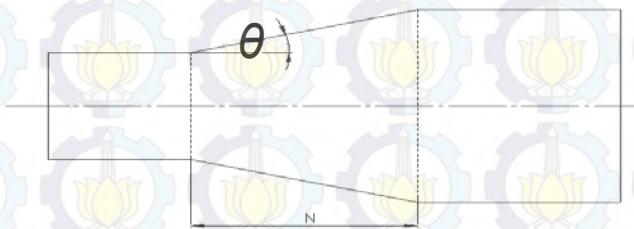


Separasi

Performa
diffuser



Tujuan

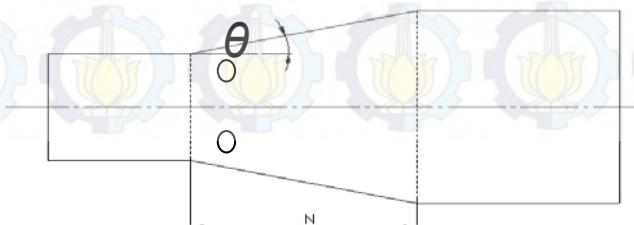


Model *conical diffuser* tanpa VG

Perbandingan



Model *conical diffuser* dengan VG



- Profil Kecepatan
- Profil intensitas turbulensi
- Distribusi C_p
- Total pressure loss coefficient (ζ)
- Distribusi C_f

Batasan Masalah

Kondisi aliran pada *inlet test section* adalah *steady, incompressible* dan *viscous*

Aliran yang diamati adalah kasus aliran turbulen

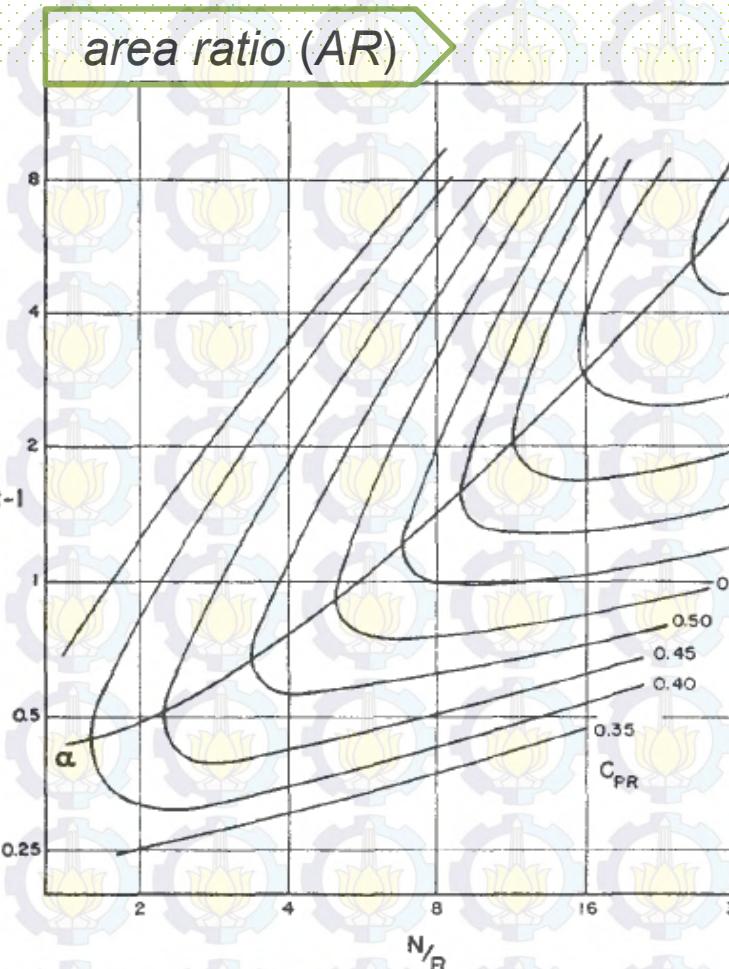
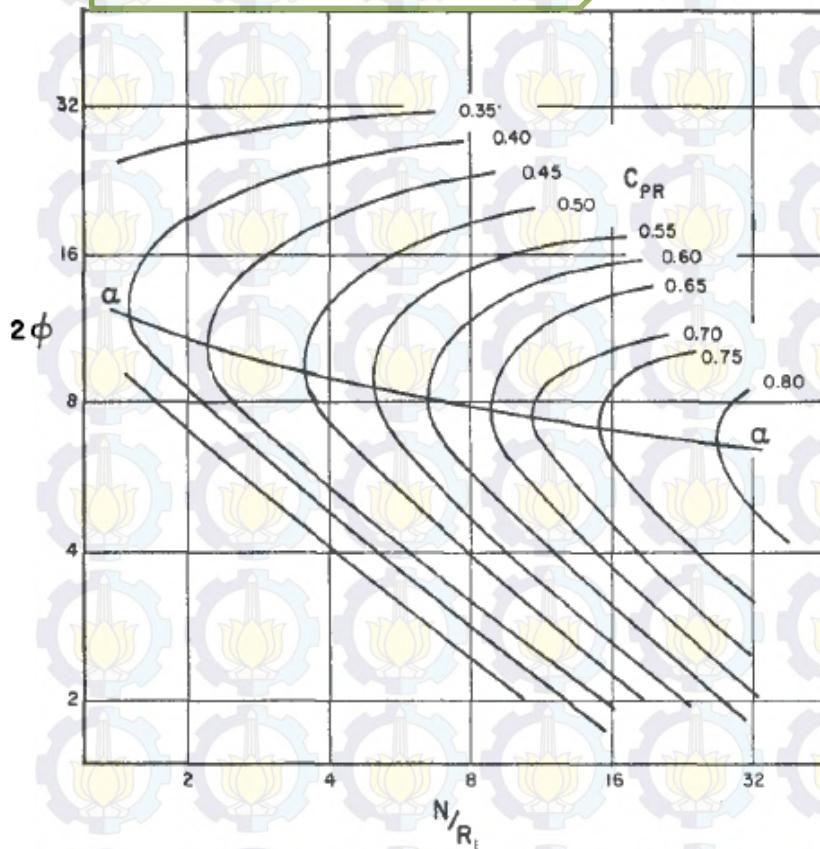
Arah aliran *uniform* di sisi masuk *test section*

Efek perpindahan panas akibat aliran fluida dalam *diffuser* dapat diabaikan

Pengaruh kekasaran permukaan pada dinding *diffuser* dapat diabaikan

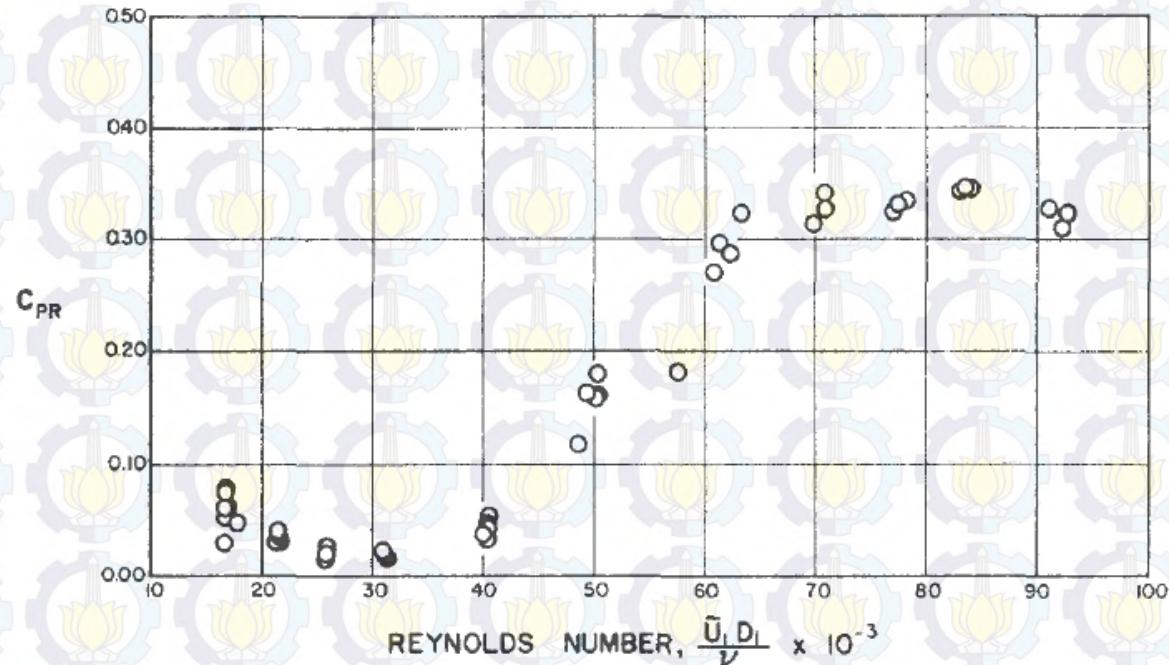
Penelitian terdahulu

- 1. Fox dan McDonald (1966)
sudut divergensi (2θ)



Distribusi pressure recovery pada conical diffuser

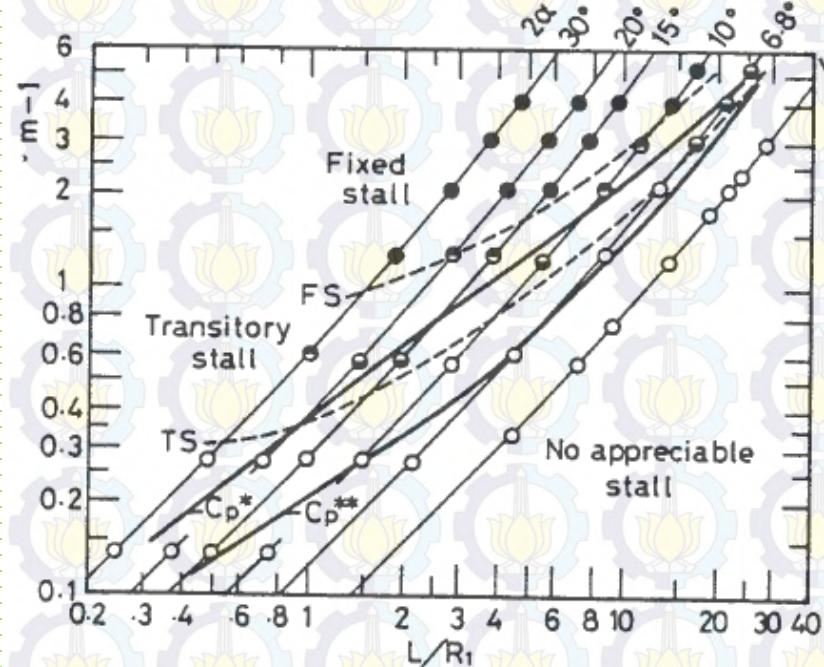
- Fox dan McDonald (1966)



Pengaruh *Reynolds number* pada performa *conical diffuser*
($2\theta = 31.2^\circ$, $N/R_1 = 4.0$)

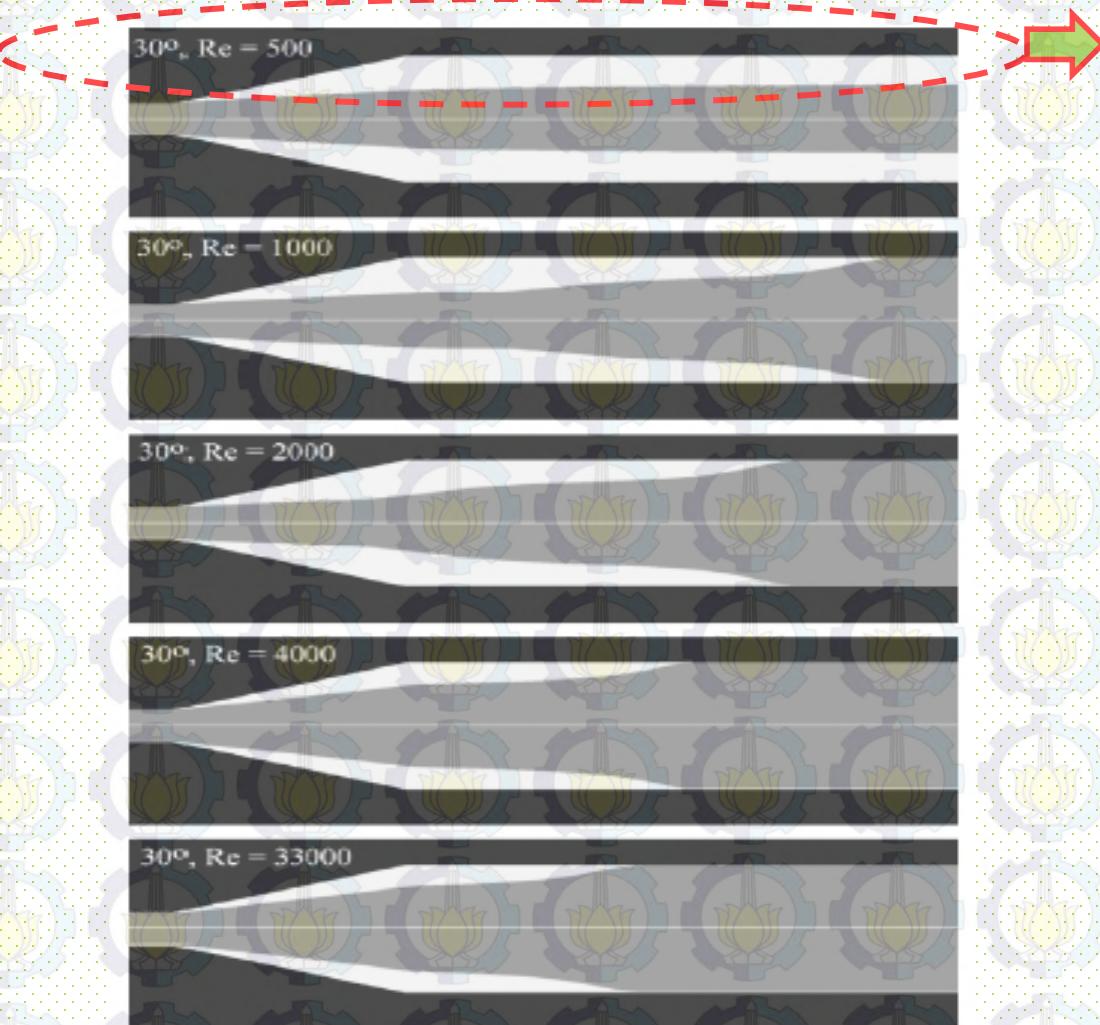
- Ishikawa dan Nakamura (1989)

Peta kestabilan conical diffuser



- Diffuser geometry with no appreciable stall.
- Diffuser geometry with intermittent transitory stall.
- Diffuser geometry with transitory stall and intermittent favorable flow.
- Diffuser geometry with fixed stall.

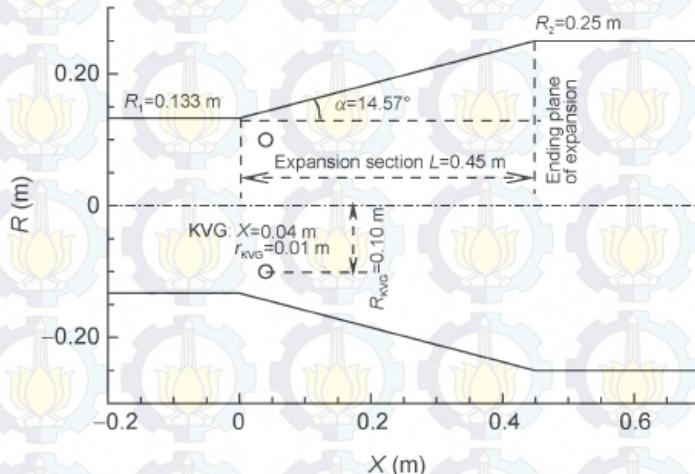
- Sparrow dkk (2009)



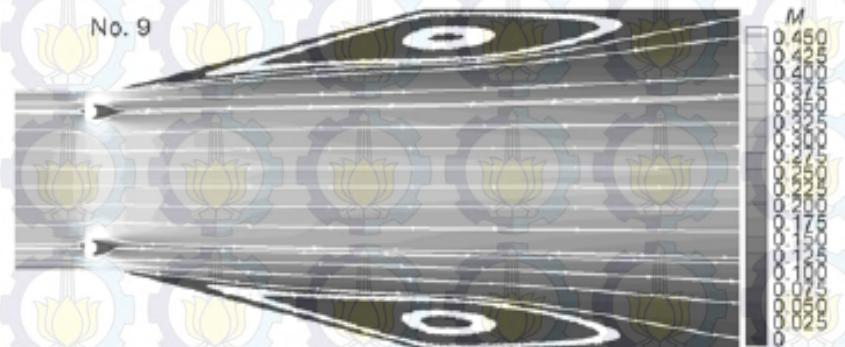
Separasi

Visualisasi aliran pada diverging duct pada sudut divergensi 30°

- Zhang dkk (2012)



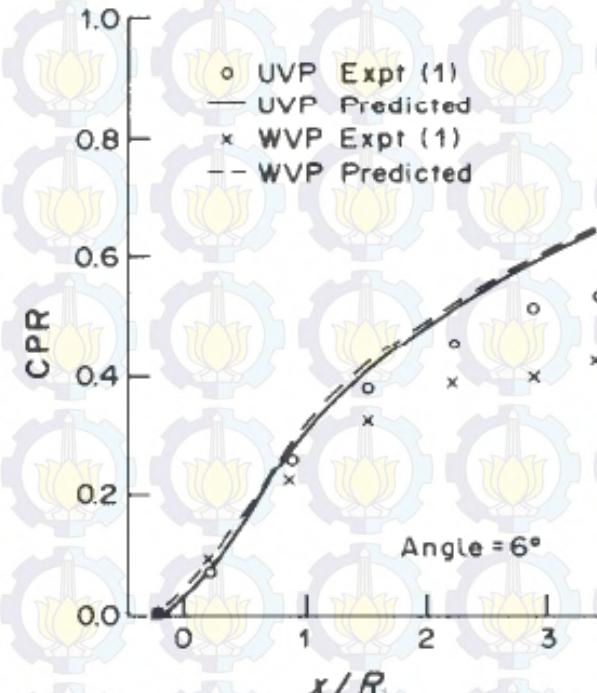
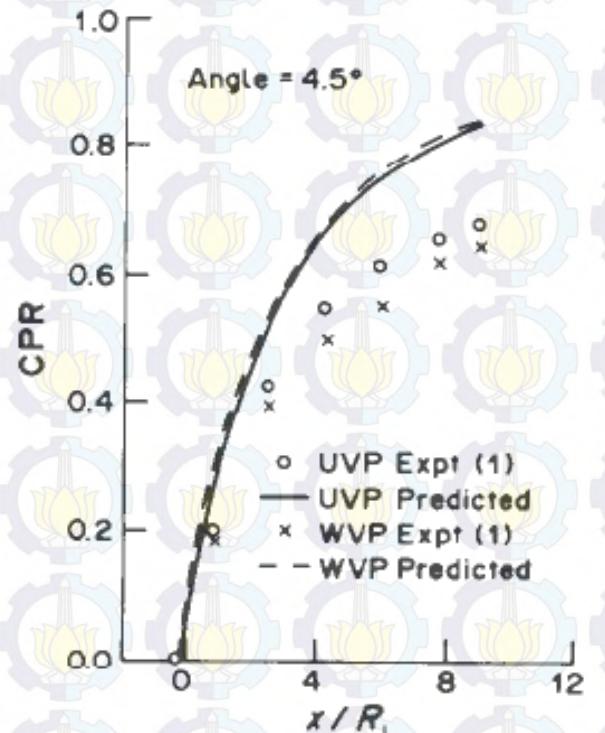
Visualisasi time averaged flow pada symmetry plane (KVG no. 9)



No.	X (m)	R (m)	r (m)	Performance coefficient	Total pressure recovery
Baseline KVG	0.04	0.10	0.01	0.4937	95.23%
KVG No. 1	0.04	0.09	0.01	0.3838	94.49%
KVG No. 2	0.04	0.11	0.01	0.4854	95.15%
KVG No. 3	0.04	0.10	0.0075	0.3524	94.37%
KVG No. 4	0.04	0.11	0.0075	0.3724	94.46%
KVG No. 5	0.04	0.12	0.0075	0.4222	94.88%
KVG No. 6	0.04	0.10	0.005	0.3258	94.33%
KVG No. 7	0.04	0.11	0.005	0.3247	94.32%
KVG No. 8	0.04	0.12	0.005	0.3339	94.39%
KVG No. 9	-0.04	0.10	0.01	0.3578	93.44%
Uncontrolled	—	—	—	0.2465	93.99%

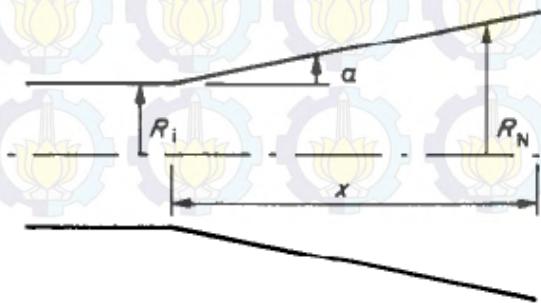
Kontrol Separasi

- Jeyachandran dan Ganeshan (1988)

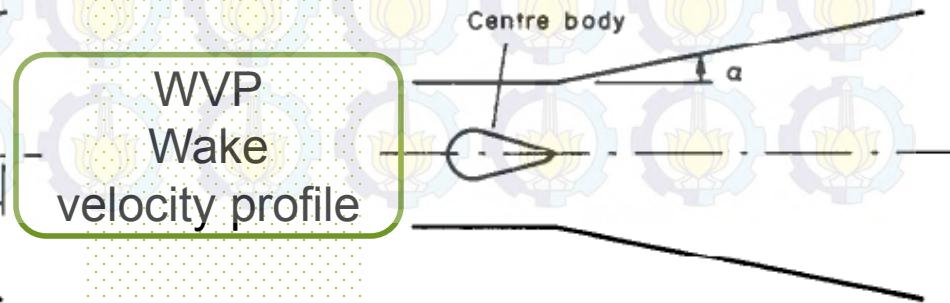


Perbandingan hasil eksperimen dan prediksi (numerik)

UVP
Uniform
velocity profile



WVP
Wake
velocity profile



Preprocessing

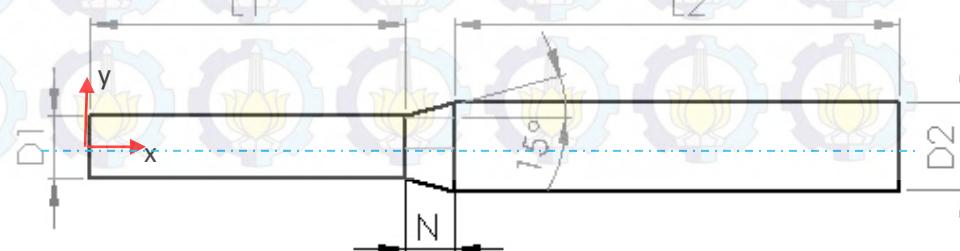
Permodelan pada Gambit

Model tanpa VG

Tampak luar



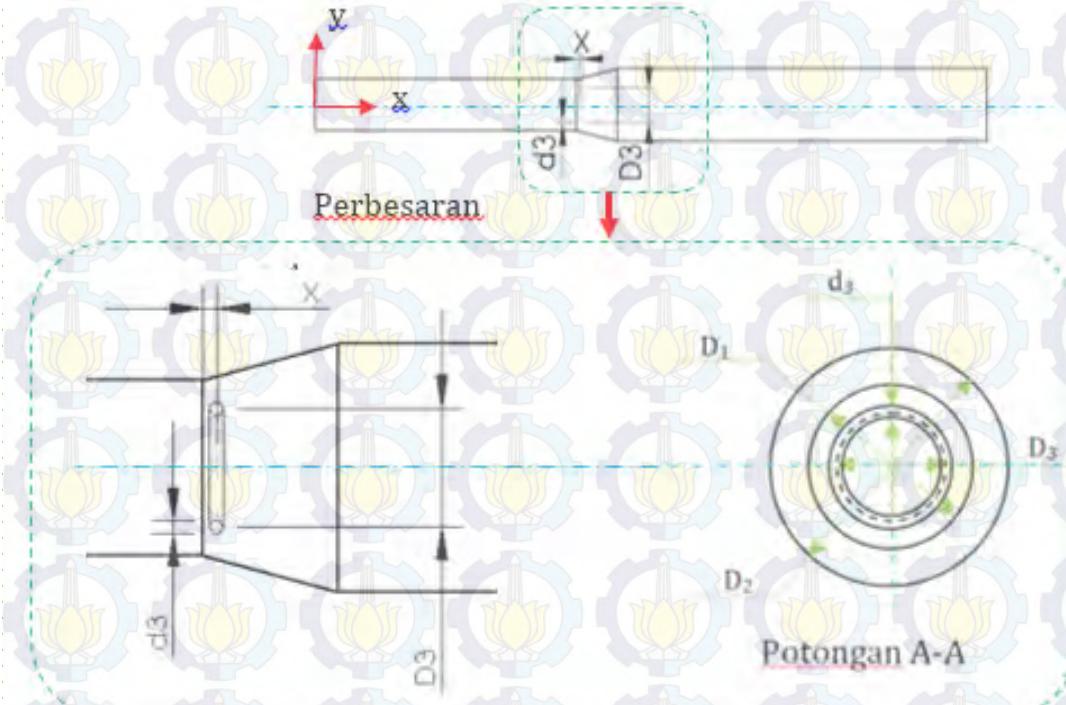
Tampak Samping



Dimensi	Nilai
Panjang upstream channel (L_1)	200 mm
Panjang diffuser (N)	31, 108.9, dan 136.5 mm
Panjang downstream channel (L_2)	$8D_2$
Diameter inlet (D_1)	40 mm
Diameter inlet (D_2)	(56.2, 98, dan 113.2) mm
Sudut divergensi (θ)	30°
AR (area ratio)	2, 6, dan 8

Model dengan VG

Tampak Samping model modifikasi



Vortex generator

Bentuk VG	circular ring
Diameter VG (D_3/D_1)	0.75
Diameter penampang VG (d_3/D_3)	0.1
Posisi VG (x/N)	0.1

Meshing

- Kecepatan = 7.5 m/s dan 18 m/s
- Intensitas turbulensi = 4.7% dan 4.2%
- Length scale = $0.07 D_1 = 2.8 \text{ mm}$

- Residual monitoring konvergensi 10^{-4}

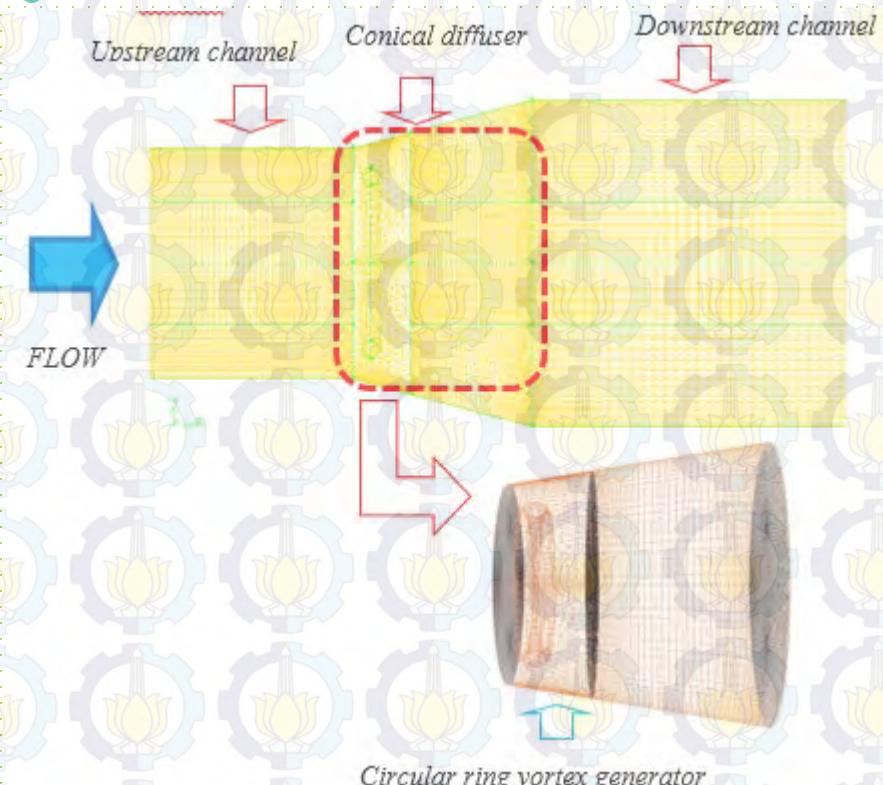
- Standard k- ϵ

- *discretization second order*

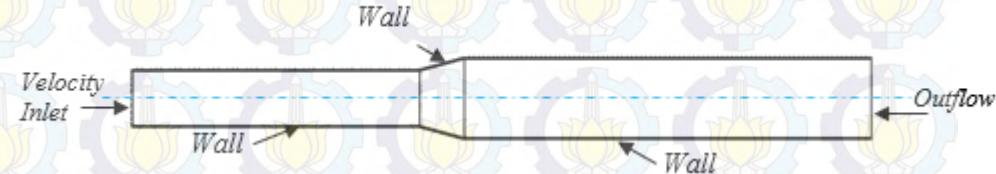
Velocity inlet

Model turbulensi

Solution



Boundary Conditions

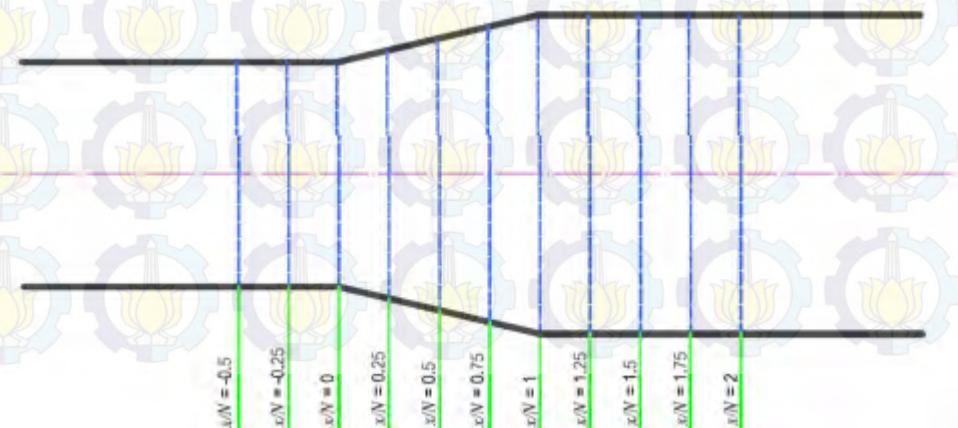


Grid Independency

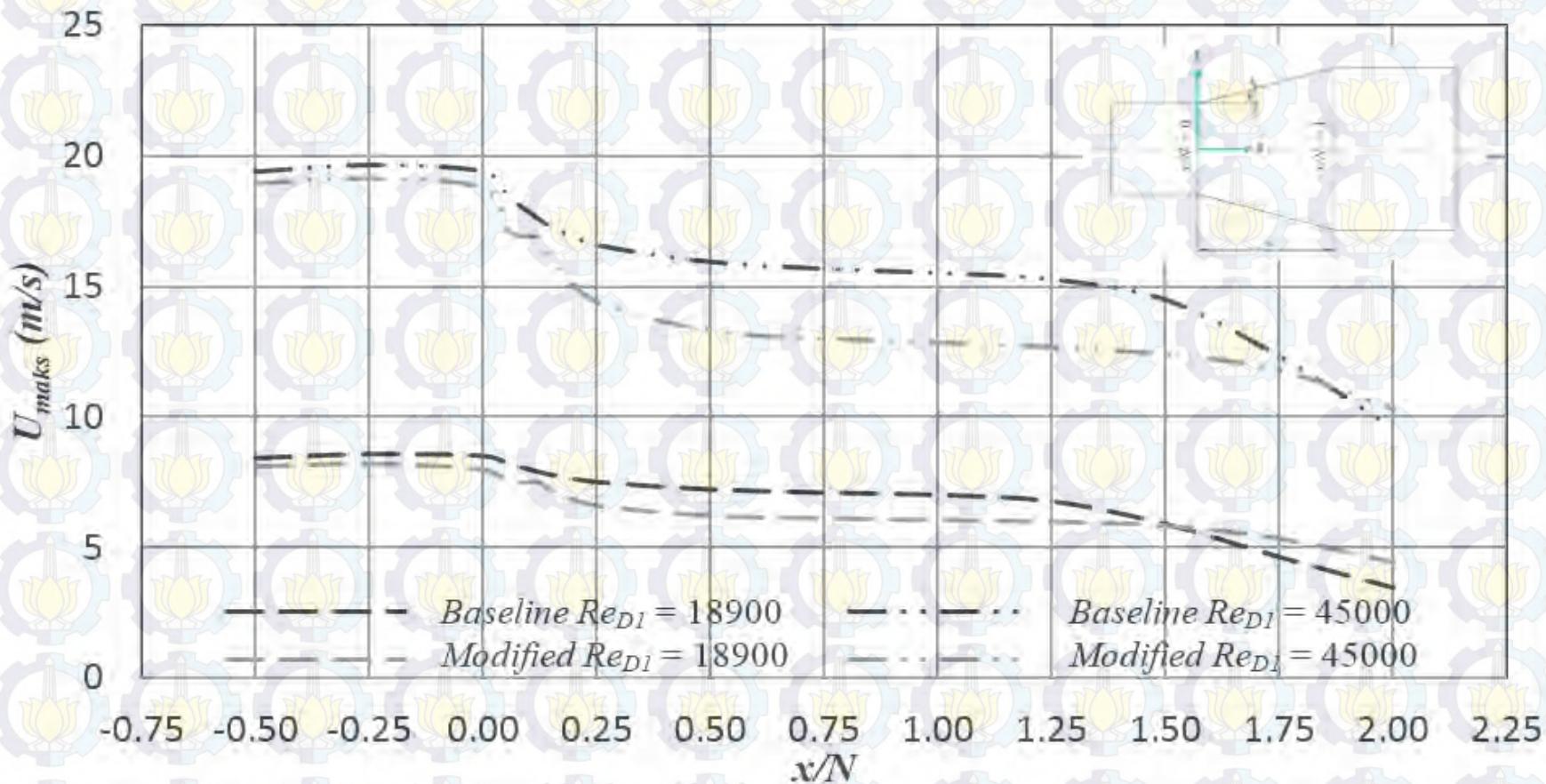
Model <i>MeshPo</i>	Jumlah Grid	$P_{02} (Pa)$ (1.587*)	Perubahan
		Nilai	
1	801000	1.116	0.296
2	971520	1.201	0.243
3	1225000	1.348	0.151
4	1706250	1.791	0.128
5	1800000	1.793	0.129

*) Data Priyadarshan dan Prasad

Posisi pengambilan data

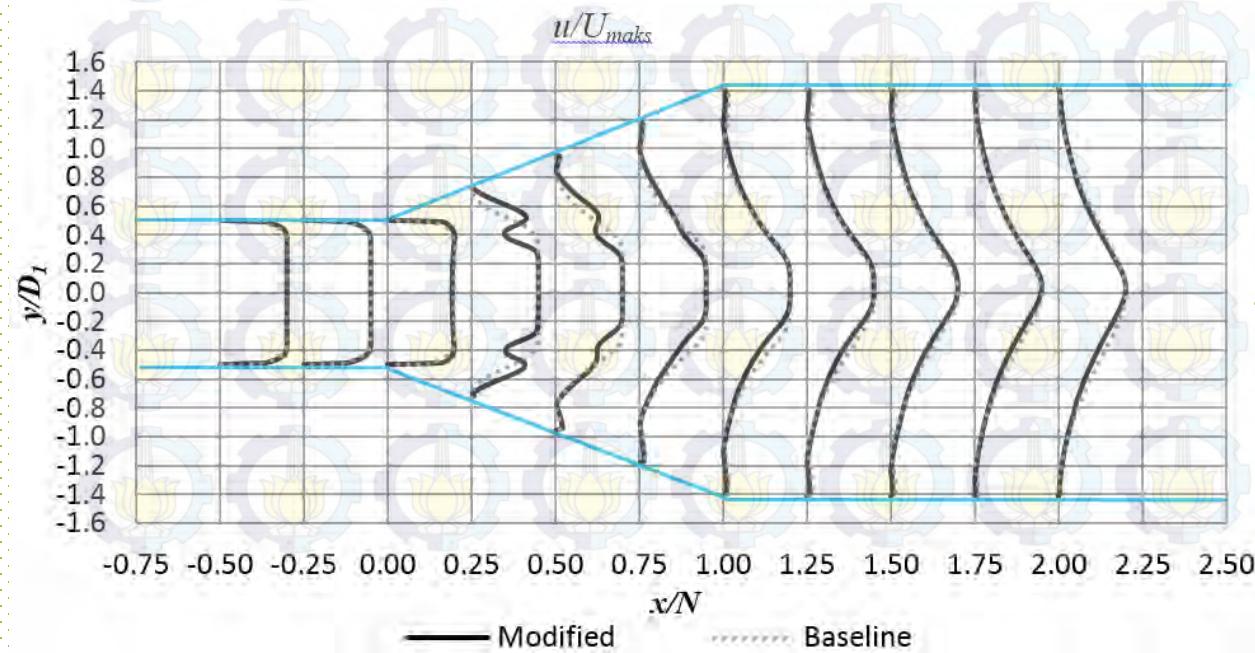
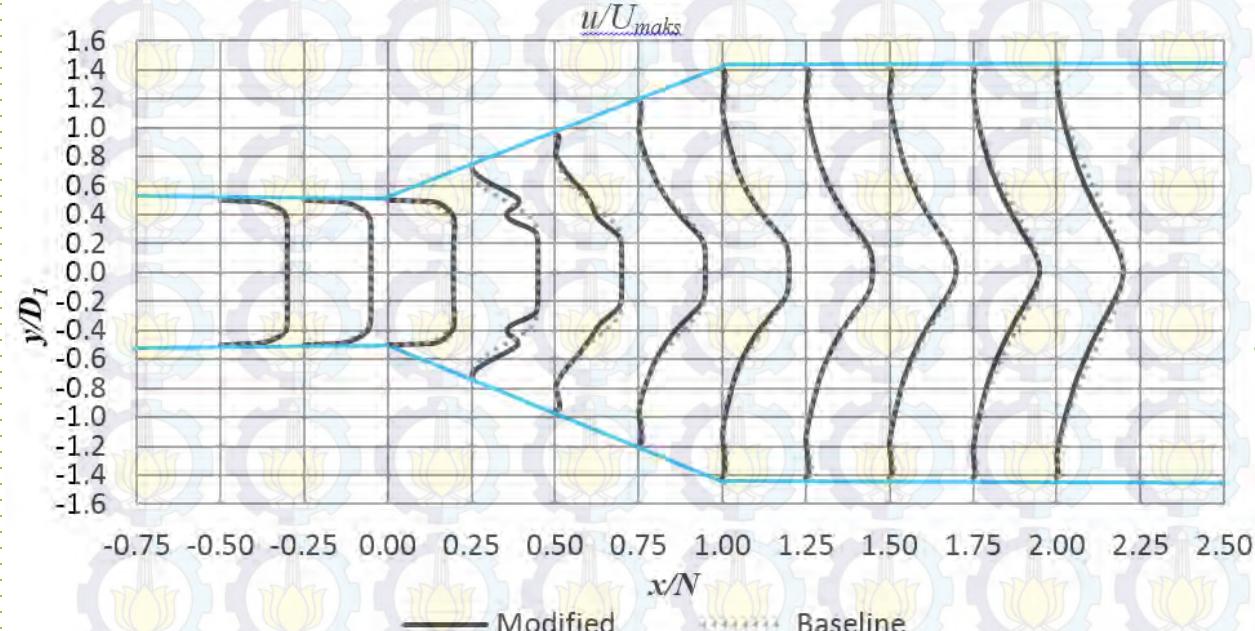


Distribusi U_{maks} di dalam diffuser: AR 8



Profil Kecepatan AR 8

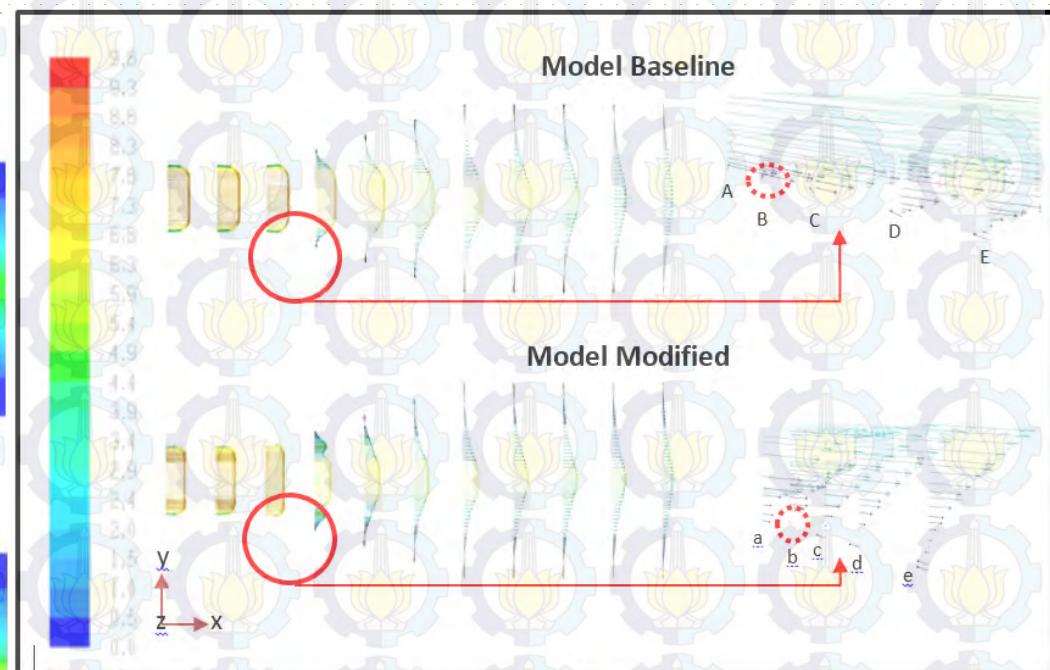
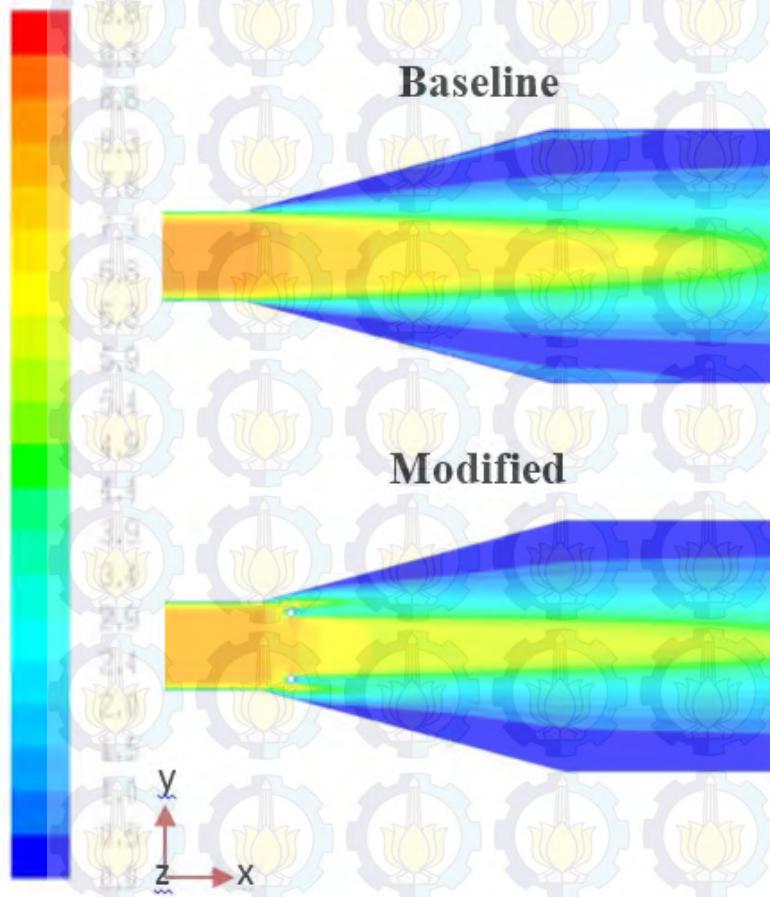
$$Re_{D1} = 1.89 \times 10^4$$



$$Re_{D1} = 4.50 \times 10^4$$

Visualisasi kontur & vektor kecepatan: AR 8

$$Re_{D1} = 1.89 \times 10^4$$



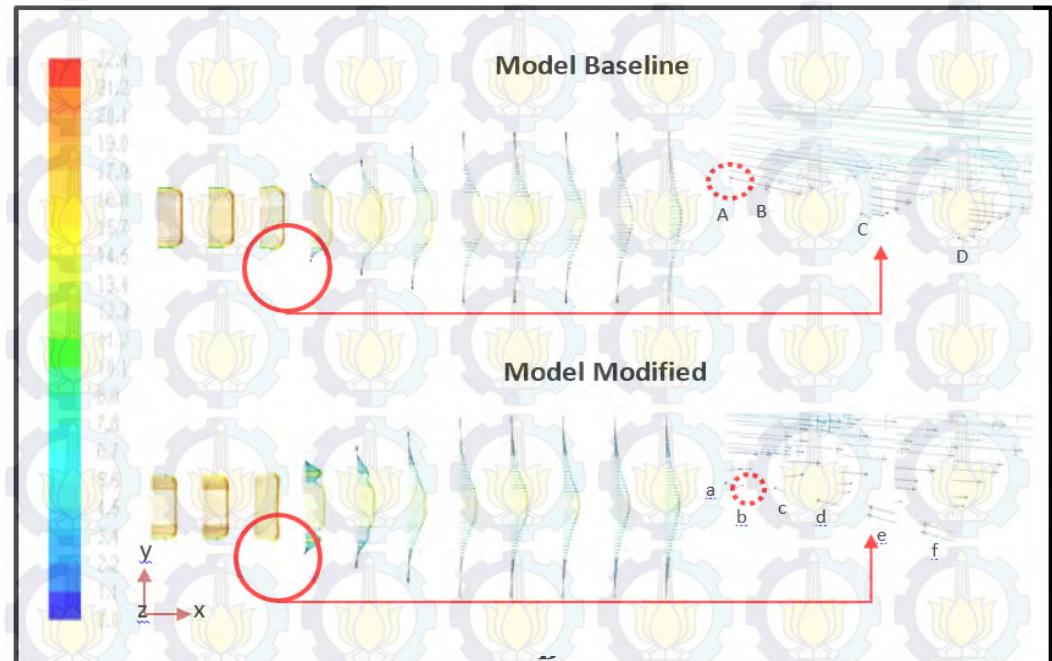
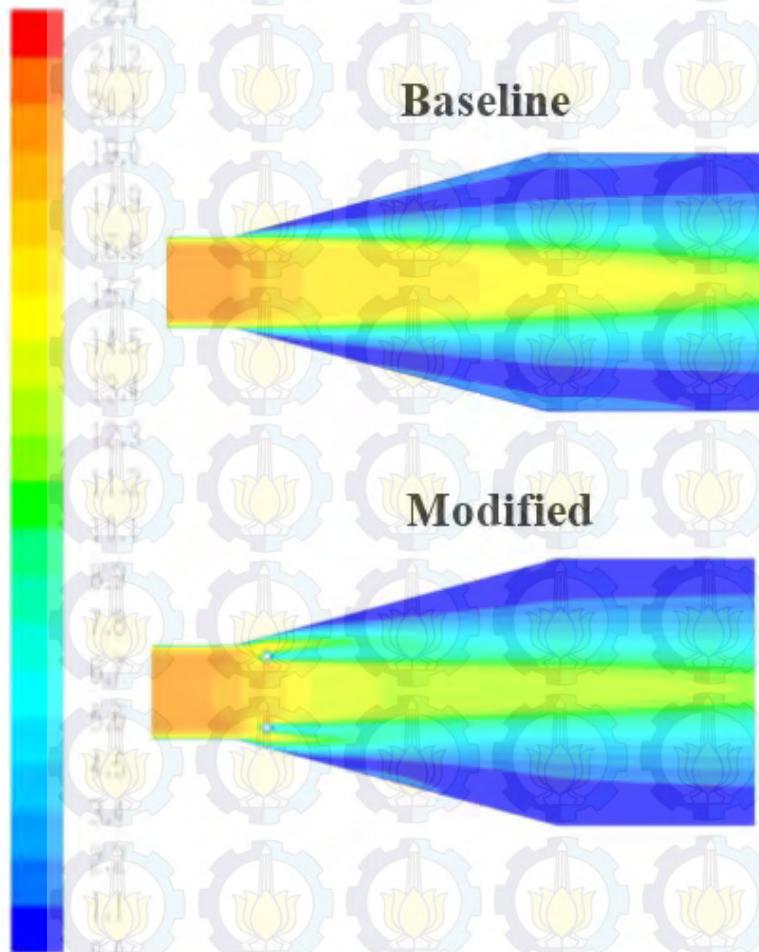
Posisi gambar A:

- A : $x/N = 0.075$
- B : $x/N = 0.085$
- C : $x/N = 0.1$
- D : $x/N = 0.125$
- E : $x/N = 0.5$

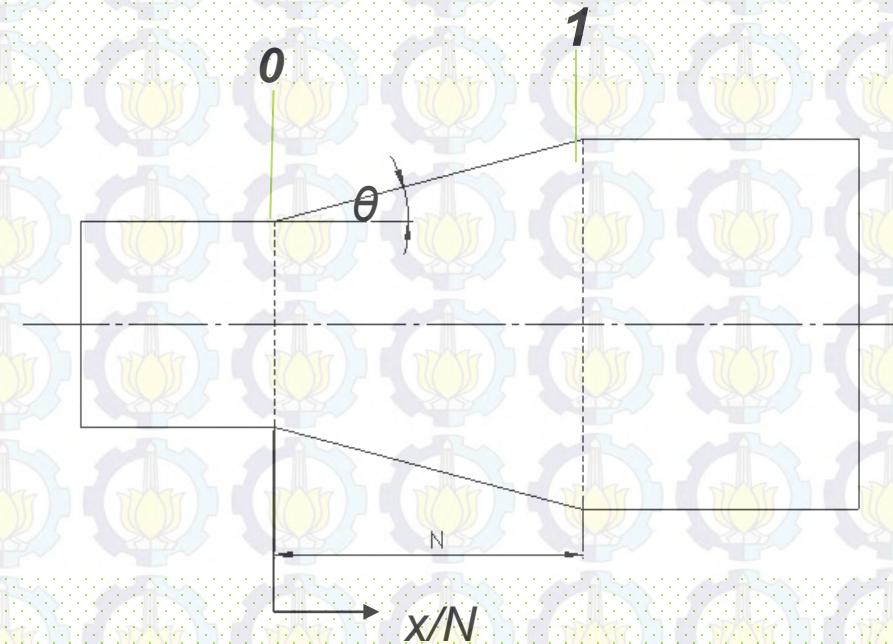
- a : $x/N = 0.2$
- b : $x/N = 0.21$
- c : $x/N = 0.22$
- d : $x/N = 0.23$
- e : $x/N = 0.25$

Visualisasi kontur & vektor kecepatan: AR 8

$$Re_{D1} = 4.50 \times 10^4$$

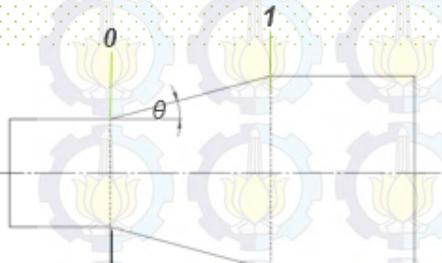
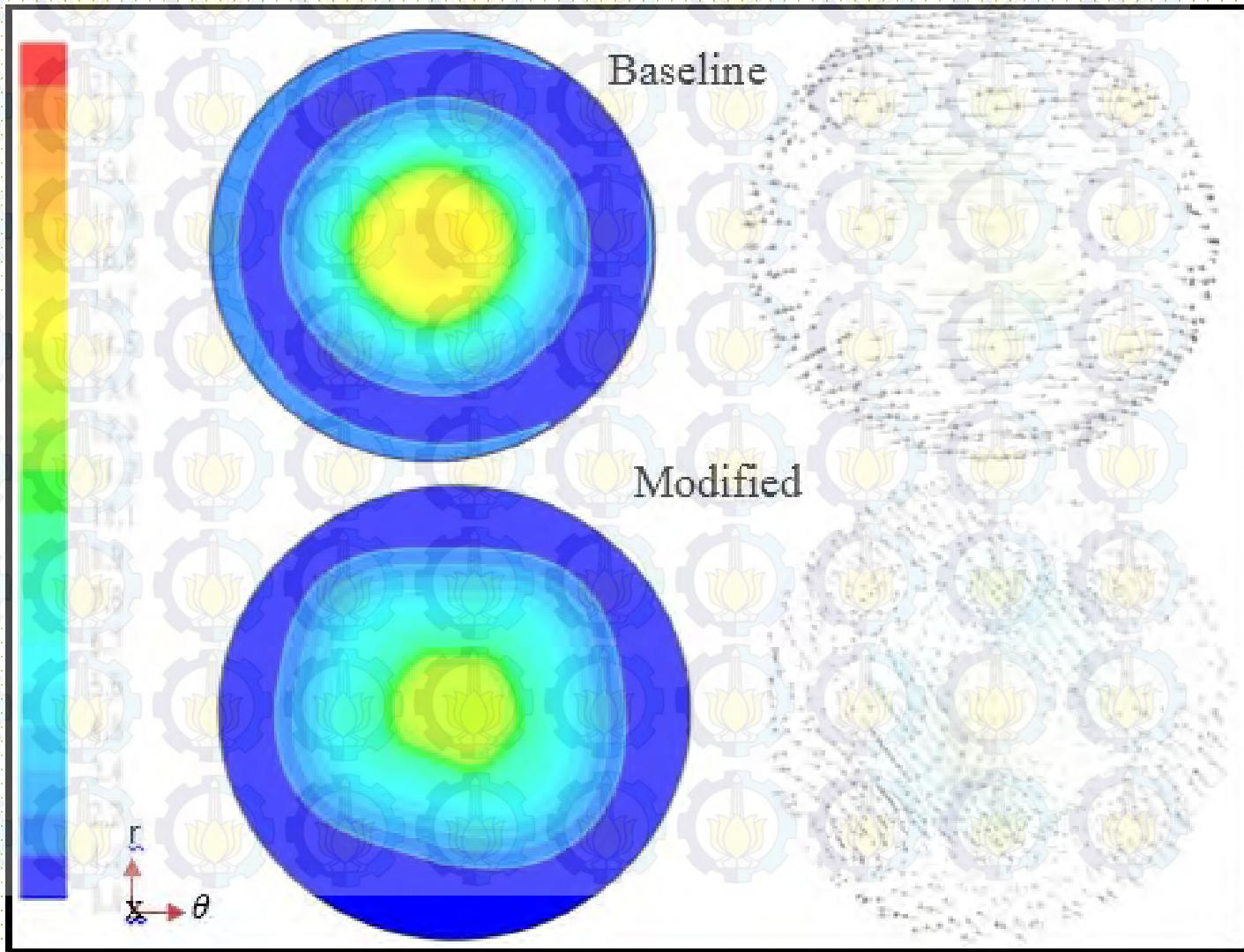


Separation point

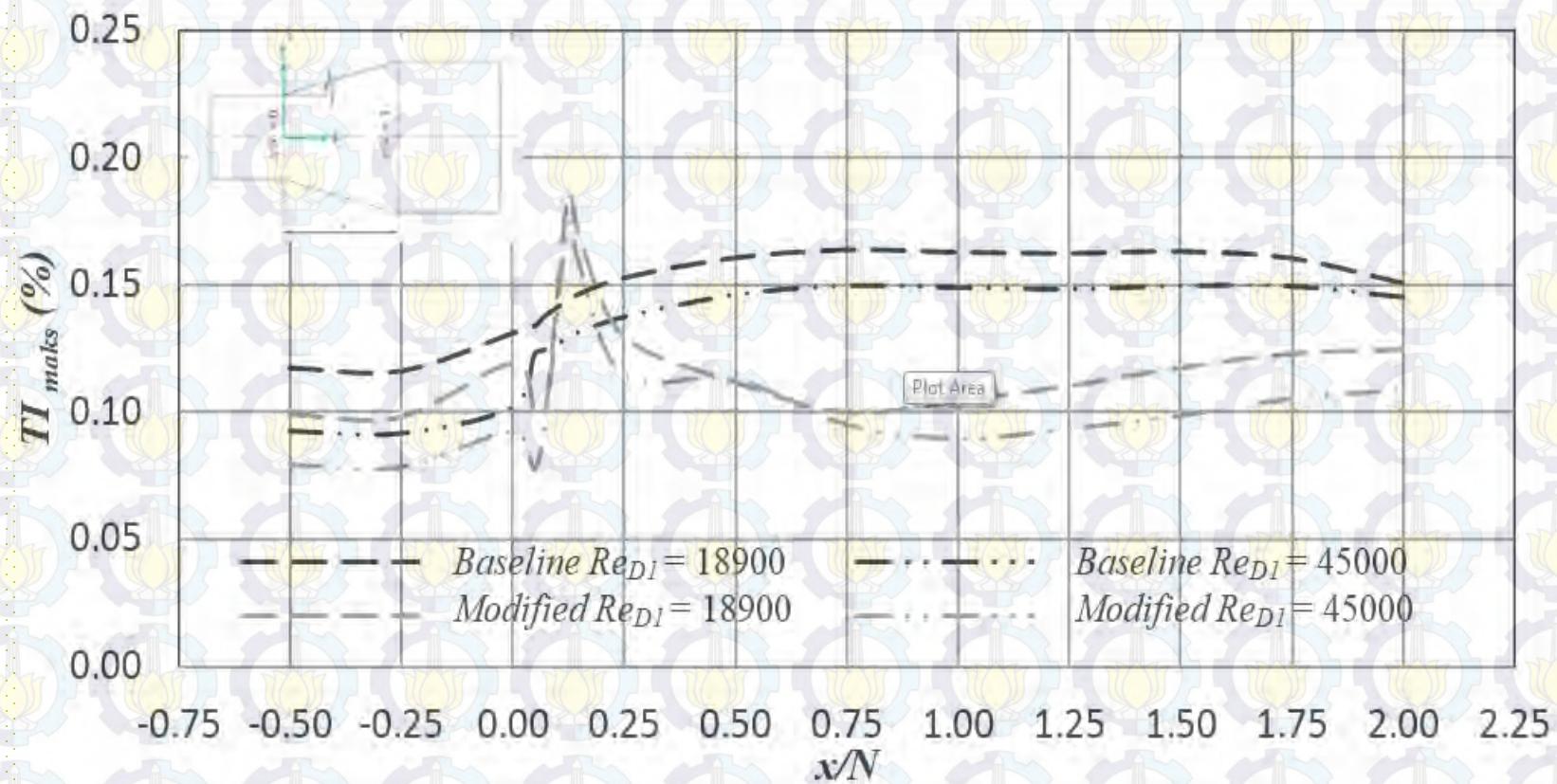


Area Ratio	Bilangan Reynolds (Re_D)	Posisi Separation point (x/N)	
		Baseline	Modified
2	1.89×10^4	0.350	0.500
	4.50×10^4	0.400	-
6	1.89×10^4	0.125	0.270
	4.50×10^4	0.150	0.280
8	1.89×10^4	0.075	0.210
	4.50×10^4	0.090	0.212

Aliran sekunder: AR 8 pada cross section $x/N = 0.75$

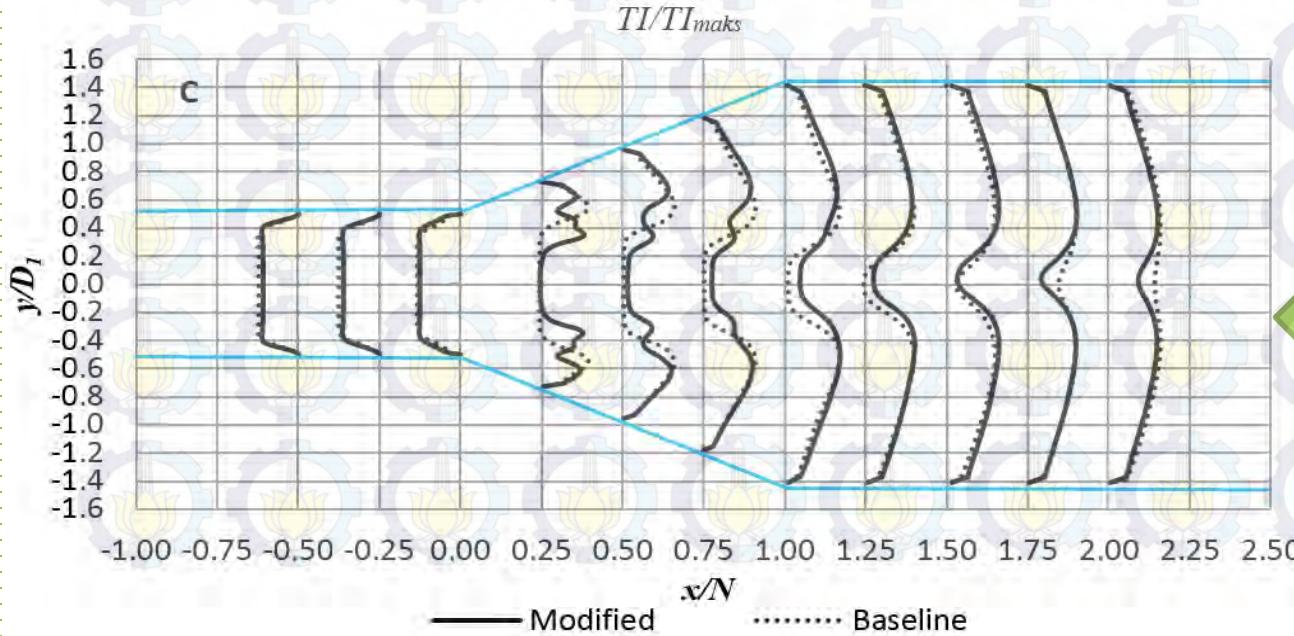
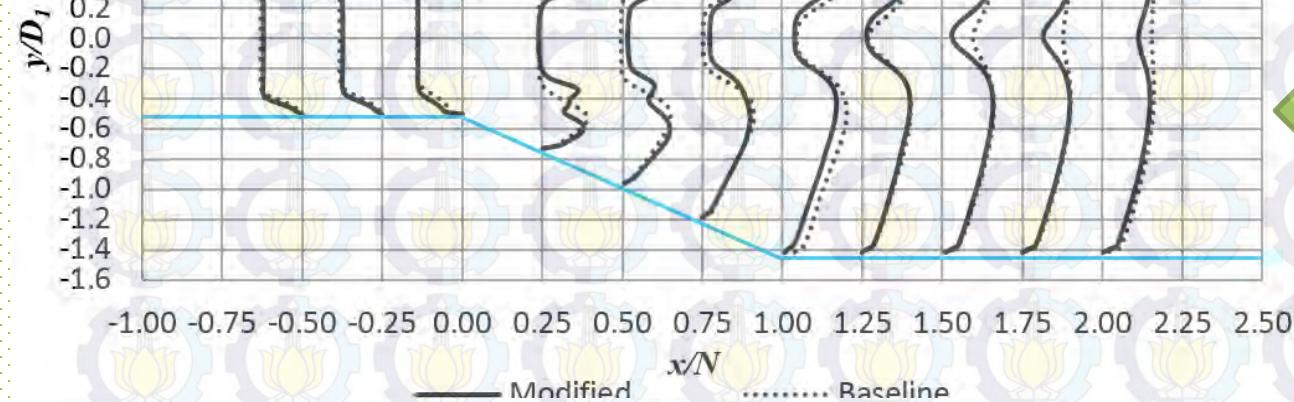


Distribusi TI_{maks} di dalam diffuser: AR 8

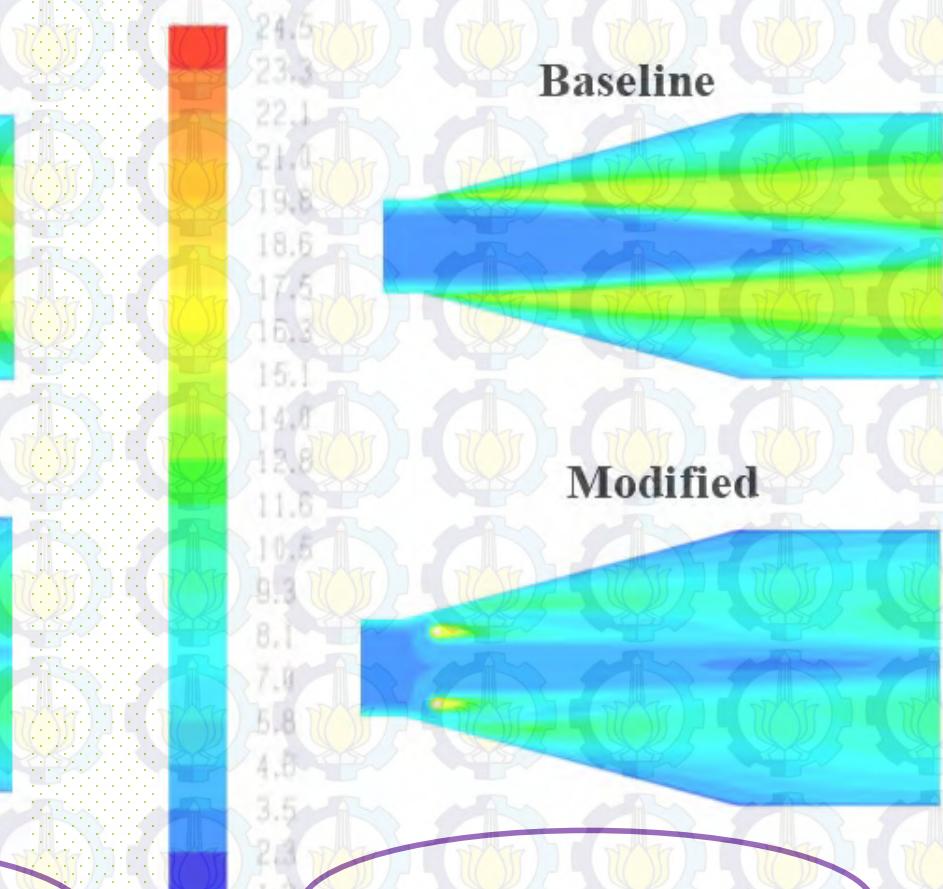
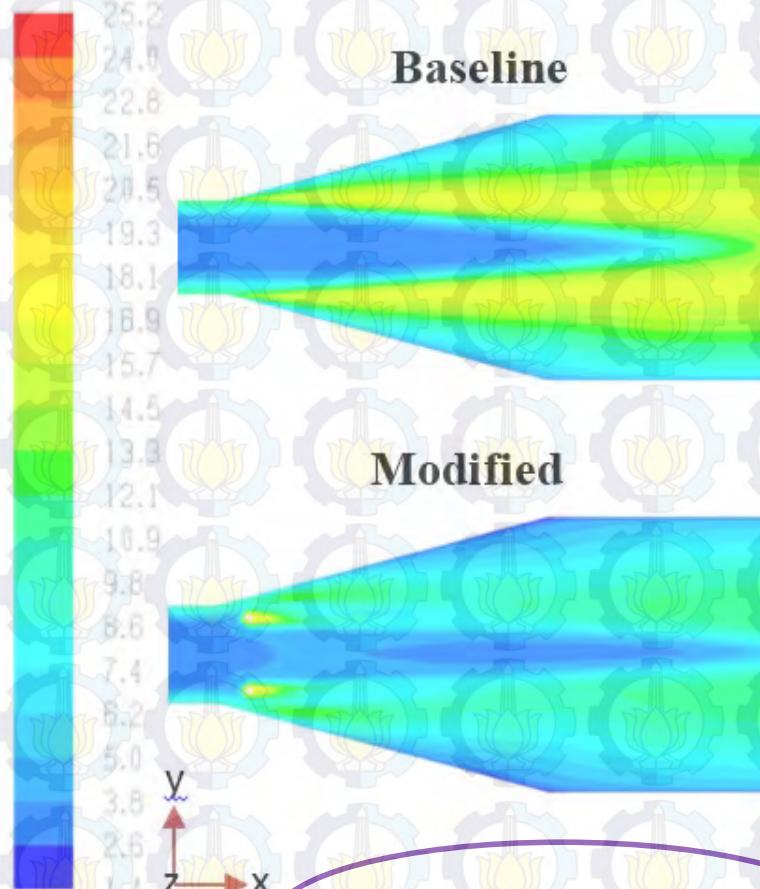


Profil Intensitas Turbulensi AR 8

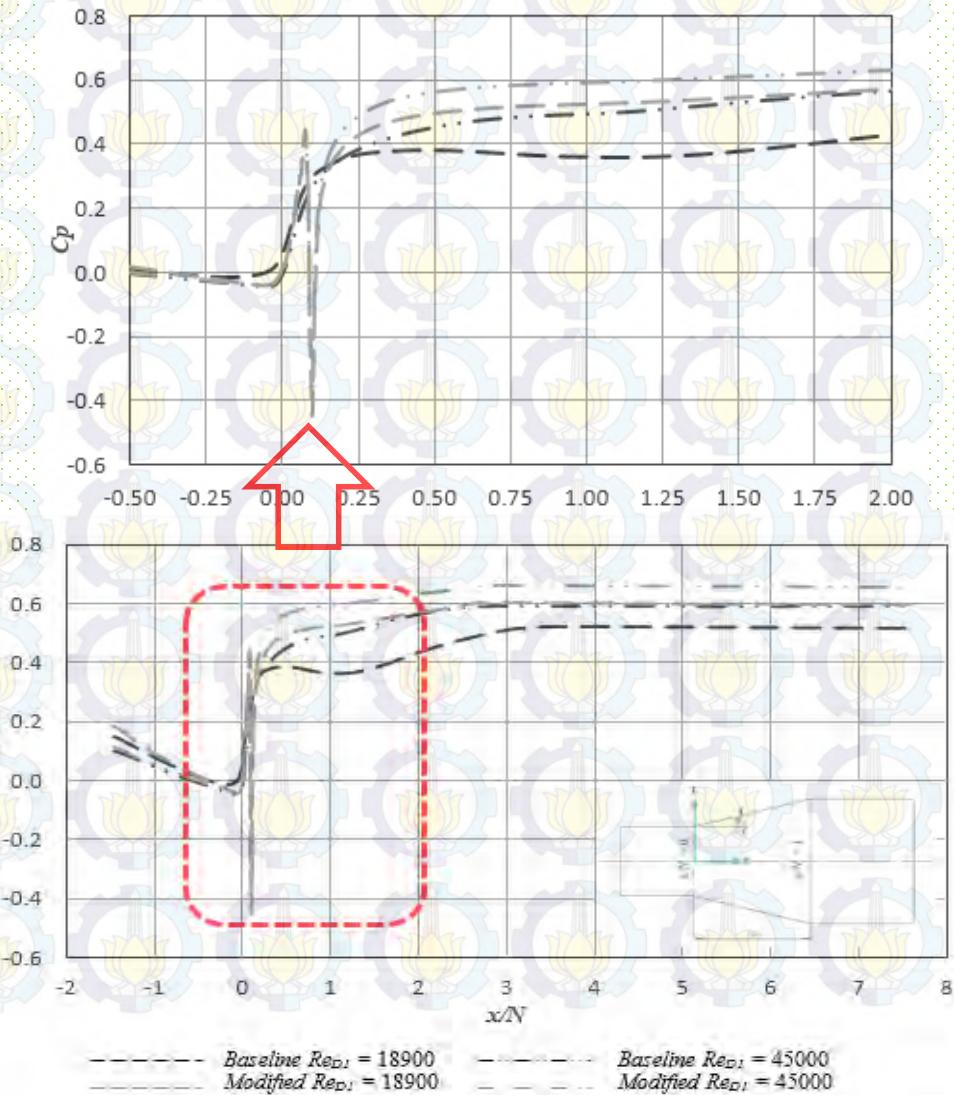
$$Re_{D_1} = 1.89 \times 10^4$$



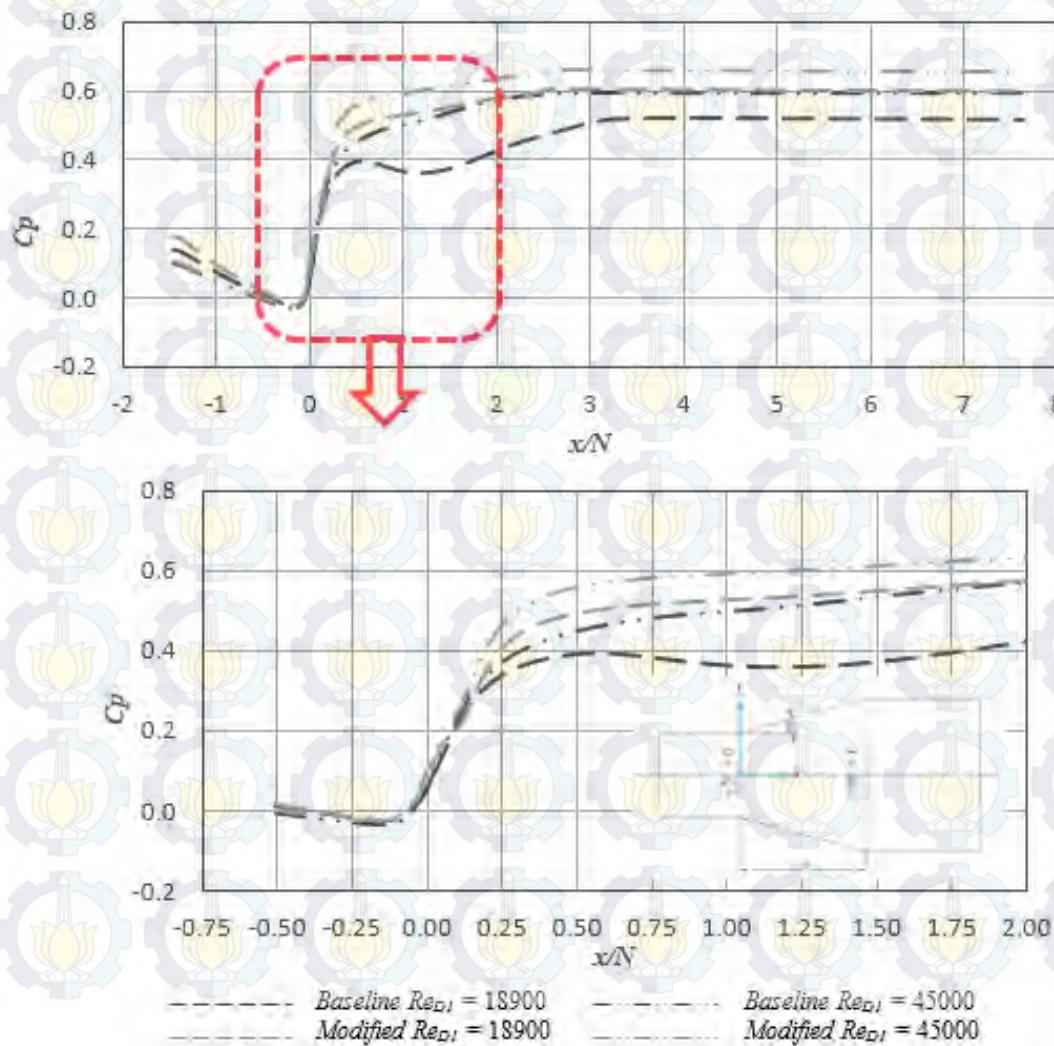
Visualisasi kontur intensitas turbulensi: AR 8



Distribusi C_p pada wall diffuser: AR 8



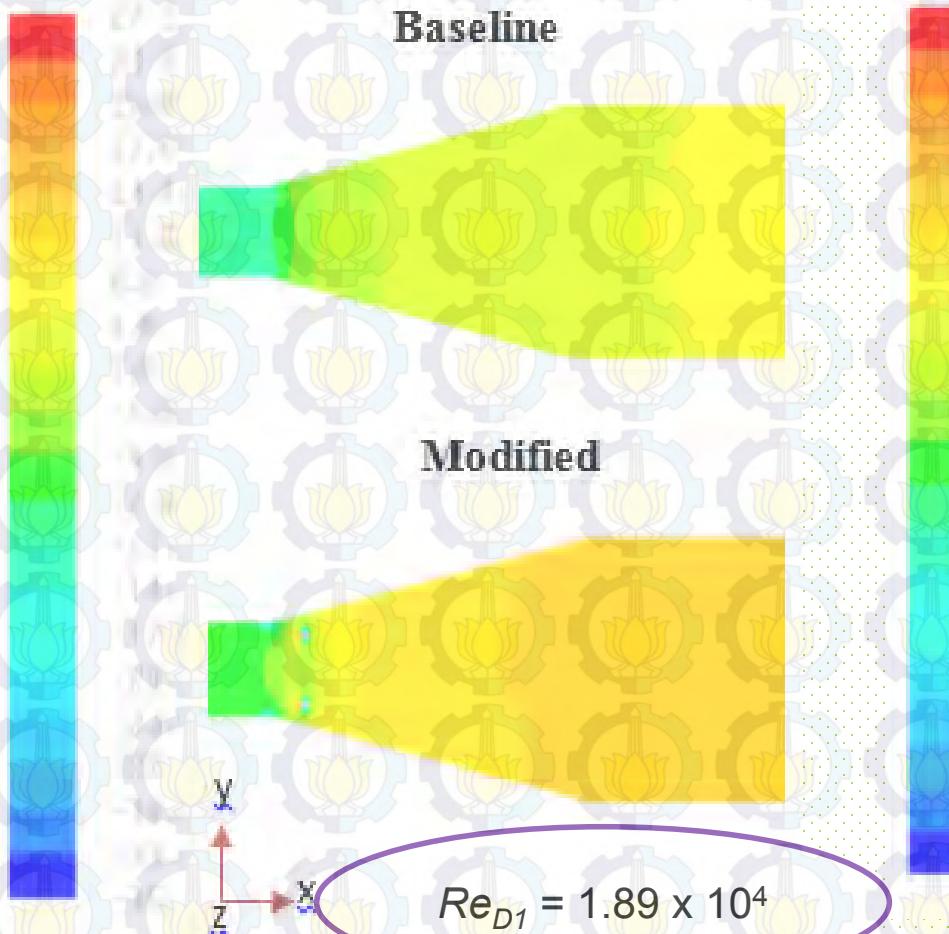
Distribusi C_p pada centerline diffuser: AR 8



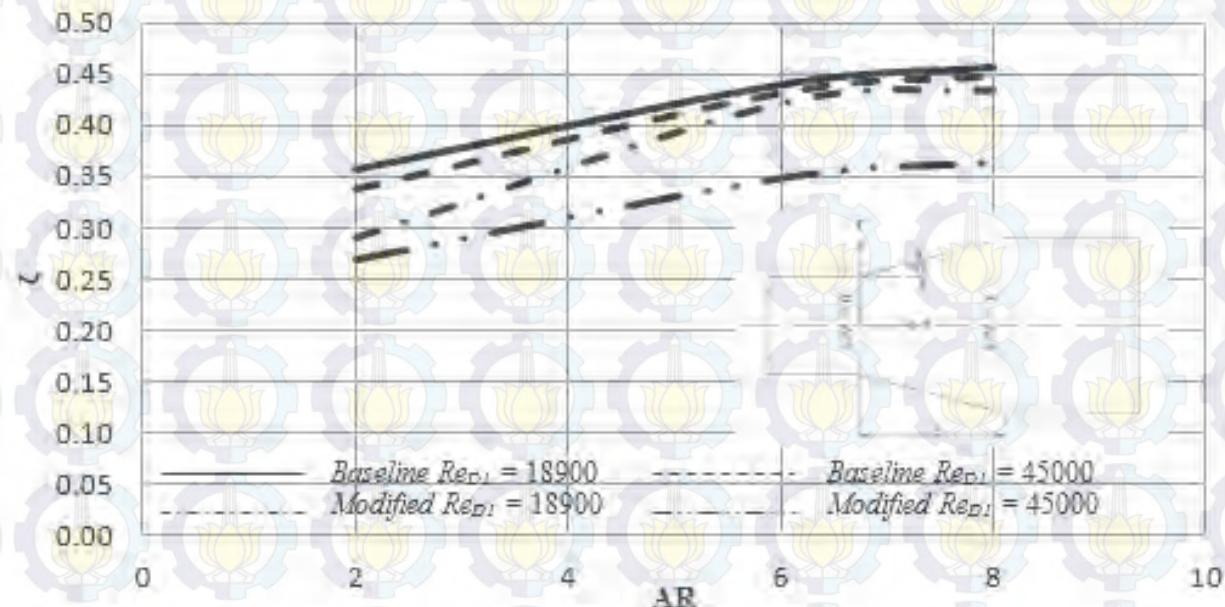
Perbandingan nilai Cp_r & Cp_{maks} model *baseline* dan *modified*

Conical Diffuser (AR)	$Re_{D1} \times 10^{-4}$	Model Baseline		Model Modified	
		Cp_r	Cp_{maks}	Cp_r	Cp_{maks}
2	1.89	0.386	0.573	0.278	0.964
	4.50	0.414	0.594	0.332	0.687
6	1.89	0.476	0.596	0.505	0.619
	4.50	0.484	0.608	0.586	0.673
8	1.89	0.488	0.573	0.507	0.605
	4.50	0.496	0.585	0.584	0.661

Visualisasi kontur tekanan statis (Pa_{gauge}): AR 8

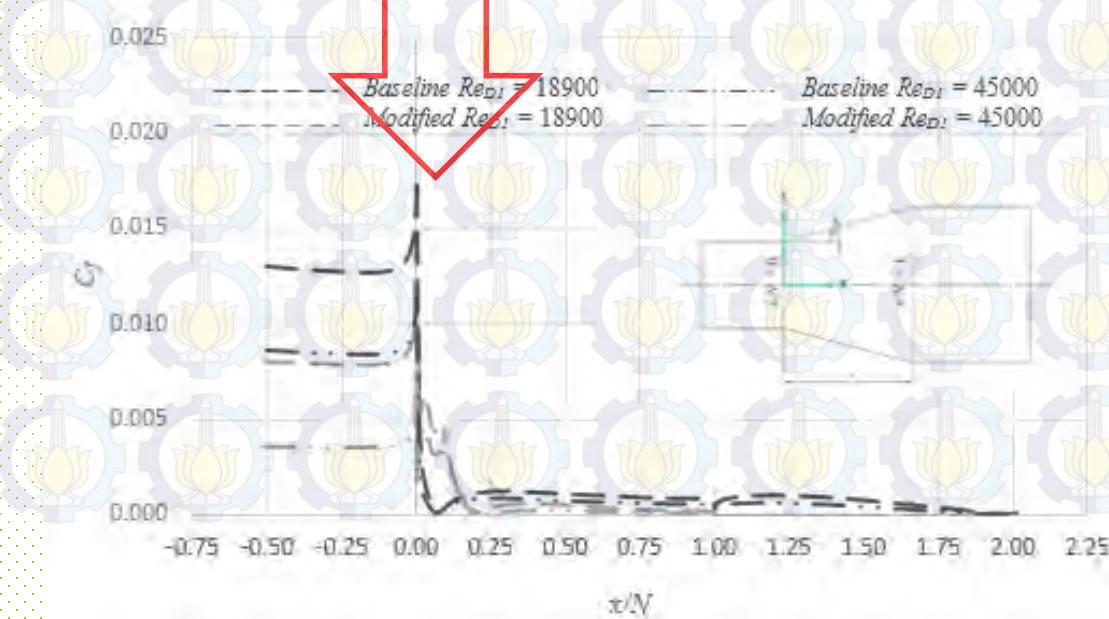
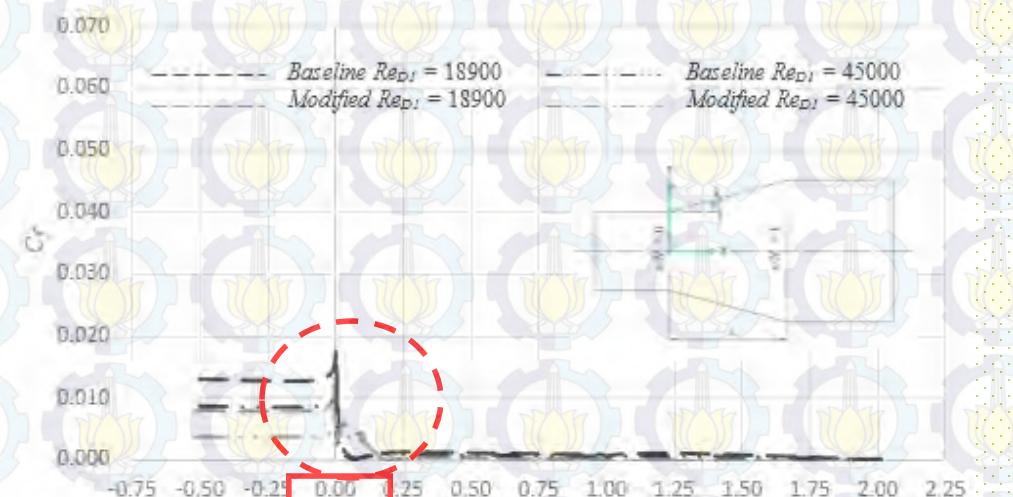


Total Pressure Loss Coefficient (ζ)



AR	2θ	$Re (10^4)$	ζ pada outlet diffuser		Reduksi ζ (%)
			Tanpa VG	Dengan VG	
2	30°	1.89	0.356	0.290	18.54
		4.50	0.337	0.269	20.20
6	30°	1.89	0.439	0.422	3.87
		4.50	0.432	0.347	19.67
8	30°	1.89	0.457	0.435	4.81
		4.50	0.448	0.363	18.97

Distribusi C_f : AR 8

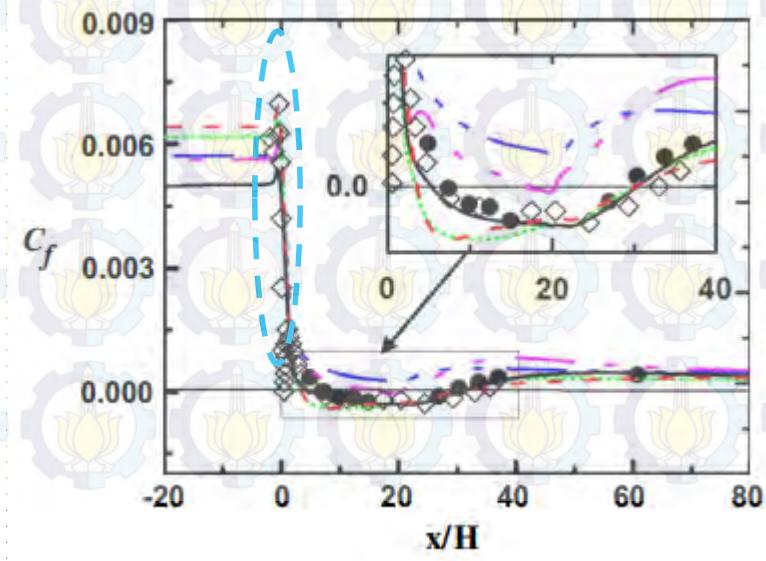
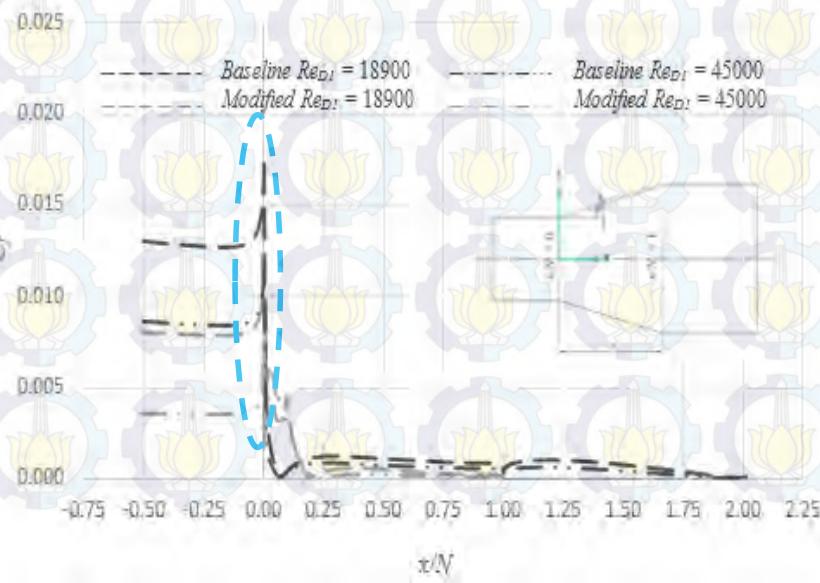


A

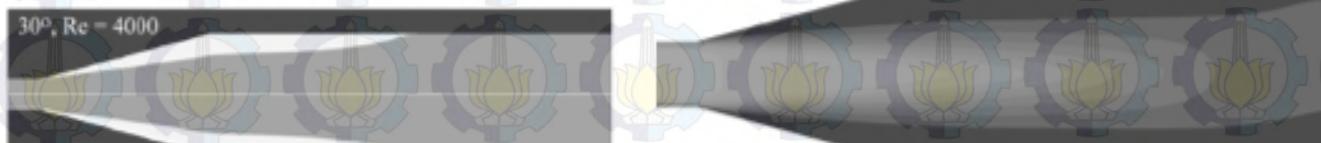
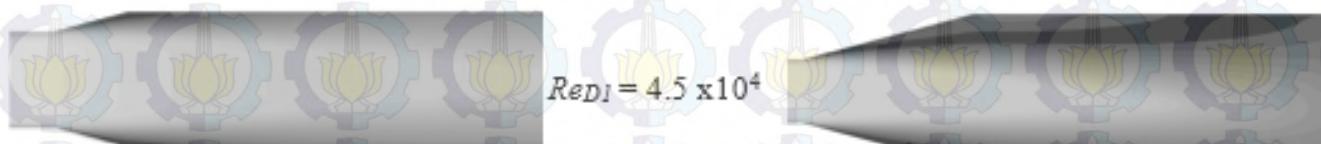
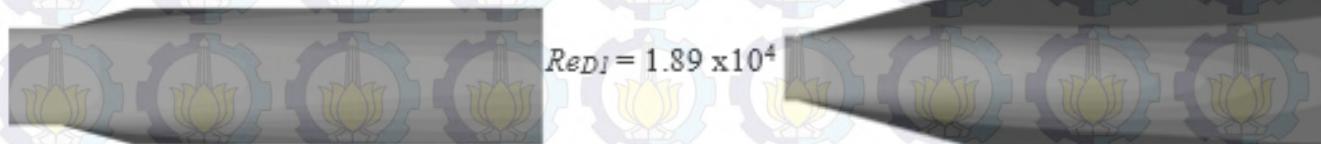
diskontinuas

*Present***B**

kontinuas

El-behery dan Hamed (2010)

Perbandingan penelitian sekarang dan terdahulu (kontur kecepatan)



$AR = 4$

$AR = Sparrow (2009)$

$AR = 8$

$AR = 2, 6, \text{ dan } 8 = present$

Perbandingan nilai Cpr

<i>Conical diffuser</i>	<i>Tipe Aliran</i>	<i>Model Modified</i>
$AR = 2$ $(2\theta) = 30^\circ$	Mach number ≤ 0.1 $Re_{D1} = 1.89 \times 10^4$ Mach number ≤ 0.1 $Re_{D1} = 4.5 \times 10^4$	Cp_r 0.278 0.332
$AR = 3.533$ $(2\theta) = 29.14^\circ$ (Zhang dkk)	Mach number = 0.45	0.4937
$AR = 6$ $(2\theta) = 30^\circ$	Mach number ≤ 0.1 $Re_{D1} = 1.89 \times 10^4$ Mach number ≤ 0.1 $Re_{D1} = 4.5 \times 10^4$	0.505 0.586
$AR = 8$ $(2\theta) = 30^\circ$	Mach number ≤ 0.1 $Re_{D1} = 1.89 \times 10^4$ Mach number ≤ 0.1 $Re_{D1} = 4.5 \times 10^4$	0.507 0.584

Kesimpulan

Dari distribusi profil kecepatan secara numerik, aliran tidak mengalami separasi hanya pada model modified dengan konfigurasi AR 2 $Re_{D_1} = 4.50 \times 10^4$

Vortex generator berpengaruh pada penundaan ataupun mengeliminasi separasi

Area Ratio (AR)	Bilangan Reynolds $Re_{D_1} \times 10^{-4}$	Penundaan separasi $(\Delta x/N) \times 100\%$
2	1.89	15.0
	4.50	Tidak terjadi separasi
6	1.89	14.5
	4.50	13.0
8	1.89	13.5
	4.50	12.2

Adanya peningkatan nilai C_{pr} dan $C_{p_{maks}}$ setelah model dimodifikasi dengan circular ring vortex generator

Saran

- | Melakukan penelitian dengan konfigurasi dan bentuk *vortex generator* yang lain.
- | Melakukan penelitian dengan variasi model turbulensi.
- | Melakukan penelitian secara eksperimen.



Terimakasih

Mohon kritik dan saran untuk kesempurnaan
Tesis ini