Sumario

1. ANEXO A: CONFIGURACIÓN DE LAS SIMULACIONES EN FLUENT

En el siguiente Anexo se presenta las configuraciones que se han utilizado en las simulaciones con Fluent. Para ser de una forma rápida y clara estos resultados se presentan mediante una Tabla.

SET UP - 1

# of Processors			**1**	
SOLVER		*Solver*	Segragated	
		Formulation	Implicit	
		Space	3D	
		Time	Steady	
		Velocity Formulation	Absolute	
		Gradient Option	Cell Based	
		Porous Formulation	Superficial Velocity	
ENERGY		*Energy Equation*	Enable	
MATERIALS	*AIR*	*Density*	*Incompresible-Ideal-Gas*	*kg/m3*
		Cp	1007,000000000	*J/kg·K*
		Th.Conduct	0,028500000	*w/m·K*
		Viscosity	0,000020033	*kg/m·s*
	AL.	*Density*	2700	*kg/m3*
		Cp	899	*J/kg·K*
		Th.Conduct	229	*w/m·K*
SOLUTION CONTROLS	*UNDER-RELAXATION FACTORS*	Pressure	0,3	
		Density	1	
		Body Forces	1	
		Momentum	0,7	
		Turbulence Kinetic Energy	0,7	
		Turb. Dissipation Rate	0,7	
		Turbulent Viscosity	0,9	
		Energy	0,98	
	DISCRETIZATION	Pressure	Stndrd	
		Momentum	1st	
		Turbulence Kinetic Energy	1st	
		Turb. Dissipation Rate	1st	
		Energy	1st	

Tabla A.1: *Configuración de las simulaciones con Fluent*

SET UP - 2

VISCOUS	*Model*	K-epsilon
	K-e Model	Realizable
	Near Wall Treatment	Enhanced Wall Treatment
	Enhanced Wall Treat. Options	None
	Options	None

Tabla A.2: *Configuración del Solver en las simulaciones con Fluent*

2. ANEXO B: PROPIEDADES DE LOS MODELOS EMPLEADOS EN LAS SIMULACIONES

En este Anexo se presentan mediante Tablas las propiedades de los modelos empleados en las simulaciones. Como se verá a continuación estas tablas contienen todas las partes del modelo con una pequeña descripción así como si existe algún valor notable que mencionar.

MODEL - 1

Model	TUNEL + RAD - Model_1
Tunel	Tunel
Radiator	Model 5

Boundaries	***Type***	***Options***	***Values***	***Function***
frame_front	Wall	Heat Flux	NO	Frontal face of the frame
frame_back	Wall	Heat Flux	NO	Back face of the frame
frame_top	Wall	Heat Flux	NO	Top face of the frame
frame_bottom	Wall	Heat Flux	NO	Bottom face of the frame
frame_left	Wall	Heat Flux	NO	Left face of the frame
frame_right	Wall	Heat Flux	NO	Right face of the frame
frame_int_top	Wall	Heat Flux	NO	Internal Top face of the radiator
frame_int_bottom	Wall	Heat Flux	NO	Internal Bottom face of the radiator
frame_int_left	Wall	Heat Flux	NO	Internal Left face of the radiator
frame_int_right	Wall	Heat Flux	NO	Internal Right face of the radiator
radiator_front	Interior	None		Radiator front face
radiator_back	Interior	None		Radiator back face
frame_interior	Interior	None		Interior faces of the frame
tunel_interior	Interior	None		Interior faces of the tunel
tunel_top	Wall	Heat Flux	NO	Tunel top face
tunel_bottom	Wall	Heat Flux	NO	Tunel bottom face
tunel_left	Wall	Heat Flux	NO	Tunel left face
tunel_right	Wall	Heat Flux	NO	Tunel right face
tunel_outlet	Pressure Outlet	Gauge Pressure Backflow Temp. Back Flow Turb. Back Flow Hydr.	0 351 10% 550	Duct outlet
tunel_inlet	Velocity Inlet	Vel. Magnitude Temperature Turbulence Intensity Hydr. Diameter	20 300 10% 550	Duct inlet

Fluid Zones	***Type***	***Options***	***Values***	***Function***
rad_air	Fluid	Laminar Zone Porous Zone	YES YES	Air inside the radiator
frame	Solid	Source Terms Fixed Values	NO NO	Frame solid
tunel_air	Fluid	Laminar Zone Porous Zone	NO NO	Air through the tunel

Tabla B.1: *Características del Modelo - 1*

MODEL - 2

Model	TUNEL + RAD - Model_2
Tunel	Tunel
Radiator	Model 4

Boundaries	***Type***	***Options***	***Values***	***Function***
frame_front	Wall	Heat Flux	NO	Frontal face of the frame
frame_back	Wall	Heat Flux	NO	Back face of the frame
frame_top	Wall	Heat Flux	NO	Top face of the frame
frame_bottom	Wall	Heat Flux	NO	Bottom face of the frame
frame_left	Wall	Heat Flux	NO	Left face of the frame
frame_right	Wall	Heat Flux	NO	Right face of the frame
frame_int_top	Wall	Heat Flux	NO	Internal Top face of the radiator
frame_int_bottom	Wall	Heat Flux	NO	Internal Bottom face of the radiator
frame_int_left	Wall	Heat Flux	NO	Internal Left face of the radiator
frame_int_right	Wall	Heat Flux	NO	Internal Right face of the radiator
Placa_1	Radiator	Loss Coefficient		Radiator face in frontal face of the radiator (left)
		Heat-Transfer-Coef.		
		Temperature		
		Heat Flux		
Placa_2	Radiator	Loss Coefficient		Radiator face in frontal face of the radiator (middle left)
		Heat-Transfer-Coef.		
		Temperature		
		Heat Flux		
Placa_3	Radiator	Loss Coefficient		Radiator face in frontal face of the radiator (middle right)
		Heat-Transfer-Coef.		
		Temperature		
		Heat Flux		
Placa_4	Radiator	Loss Coefficient		Radiator face in frontal face of the radiator (right)
		Heat-Transfer-Coef.		
		Temperature		
		Heat Flux		
radiator_interior	Interior	None		Radiator Interior faces (in contact with air)
radiator_front	Interior	None		Radiator front face
radiator_back	Interior	None		Radiator back face
frame_interior	Interior	None		Interior faces of the frame
tunel_interior	Interior	None		Interior faces of the tunel
tunel_top	Wall	Heat Flux	NO	Tunel top face
tunel_bottom	Wall	Heat Flux	NO	Tunel bottom face
tunel_left	Wall	Heat Flux	NO	Tunel left face
tunel_right	Wall	Heat Flux	NO	Tunel right face
tunel_outlet	Pressure Outlet	Gauge Pressure	0	Duct outlet
		Backflow Temp.	351	
		Back Flow Turb.	10%	
		Back Flow Hydr.	550	
tunel_inlet	Velocity Inlet	Vel. Magnitude	20	Duct inlet
		Temperature	300	
		Turbulence Intensity	10%	
		Hydr. Diameter	550	

Fluid Zones	***Type***	***Options***	***Values***	***Function***
rad_air	Fluid	Laminar Zone	YES	Air inside the radiator
		Porous Zone	YES	
frame	Solid	Source Terms	NO	Frame solid
		Fixed Values	NO	
tunel_air	Fluid	Laminar Zone	NO	Air through the tunel
		Porous Zone	NO	

Tabla B.2: *Características del Modelo - 2*

MODEL - 3

Model	TUNEL + RAD - Model_3
Tunel	Tunel
Radiator	Model 3

Boundaries	***Type***	***Options***	***Values***	***Function***
frame_front	Wall	Heat Flux	NO	Frontal face of the frame
frame_back	Wall	Heat Flux	NO	Back face of the frame
frame_top	Wall	Heat Flux	NO	Top face of the frame
frame_bottom	Wall	Heat Flux	NO	Bottom face of the frame
frame_left	Wall	Heat Flux	NO	Left face of the frame
frame_right	Wall	Heat Flux	NO	Right face of the frame
rad_int_top	Wall	Heat Flux	NO	Internal Top face frame-radiator
rad_int_bottom	Wall	Heat Flux	NO	Internal Bottom face frame-radiator
rad_int_left_a	Wall	Heat Flux	NO	Internal Left face frame-radiator (in contact with air)
rad_int_left_s	Wall	Heat Flux	NO	Internal Left face frame-radiator (in contact with solid)
rad_int_right_a	Wall	Heat Flux	NO	Internal Right face frame-radiator (in contact with air)
rad_int_right_s	Wall	Heat Flux	NO	Internal Right face frame-radiator (in contact with solid)
rad_tb_fil-1	Wall	Heat Flux	NO	Top and Bottom faces of the first tub (down)
rad_tb_fil-2	Wall	Heat Flux	NO	Top and Bottom faces of the second tub (up)
rad_fb_fil-1	Wall	Heat Flux	NO	Front and Back faces of the first tub (down)
rad_fb_fil-2	Wall	Heat Flux	NO	Front and Back faces of the second tub (up)
radiator_interior_a	Interior	None		Interior face in the radiator (in contact with air)
radiator_interior_s	Interior	None		Interior face in the radiator (in contact with solid)
radiator_front	Interior	None		Radiator front face
radiator_back	Interior	None		Radiator back face
frame_interior	Interior	None		Interior faces of the frame
tunel_interior	Interior	None		Interior faces of the tunel
tunel_top	Wall	Heat Flux	NO	Tunel top face
tunel_bottom	Wall	Heat Flux	NO	Tunel bottom face
tunel_left	Wall	Heat Flux	NO	Tunel left face
tunel_right	Wall	Heat Flux	NO	Tunel right face
tunel_outlet	Pressure Outlet	Gauge Pressure Backflow Temp. Back Flow Turb. Back Flow Hydr.	0 351 10% 550	Duct outlet
tunel_inlet	Velocity Inlet	Vel. Magnitude Temperature Turbulence Intensity Hydr. Diameter	20 300 10% 550	Duct inlet

Fluid Zones	***Type***	***Options***	***Values***	***Function***
rad_air	Fluid	Laminar Zone Porous Zone	YES YES	Air inside the radiator
frame	Solid	Source Terms Fixed Values	NO NO	Frame solid
barras	Solid	Source Terms Fixed Values	NO NO	Solid parts of the radiator
tunel_air	Fluid	Laminar Zone Porous Zone	NO NO	Air through the tunel

Tabla B.3: *Características del Modelo - 3*

MODEL - 4

Model	TUNEL + RAD - Model_4
Tunel	Tunel
Radiator	Model 4

Boundaries	***Type***	***Options***	***Values***	***Function***
frame_front	Wall	Heat Flux	NO	Frontal face of the frame
frame_back	Wall	Heat Flux	NO	Back face of the frame
frame_top	Wall	Heat Flux	NO	Top face of the frame
frame_bottom	Wall	Heat Flux	NO	Bottom face of the frame
frame_left	Wall	Heat Flux	NO	Left face of the frame
frame_right	Wall	Heat Flux	NO	Right face of the frame
frame_int_top_a	Wall	Heat Flux	NO	Internal Top face frame-radiator (in contact with air)
frame_int_top_s	Wall	Heat Flux	NO	Internal Top face frame-radiator (in contact with solid)
frame_int_bottom_a	Wall	Heat Flux	NO	Internal Bottom face frame-radiator (in contact with air)
frame_int_bottom_s	Wall	Heat Flux	NO	Internal Bottom face frame-radiator (in contact with solid)
frame_int_left_a	Wall	Heat Flux	NO	Internal Left face frame-radiator (in contact with air)
frame_int_left_s	Wall	Heat Flux	NO	Internal Left face frame-radiator (in contact with solid)
frame_int_right_a	Wall	Heat Flux	NO	Internal Right face frame-radiator (in contact with air)
frame_int_right_s	Wall	Heat Flux	NO	Internal Right face frame-radiator (in contact with solid)
tub-1_horizontal	Wall	Heat Flux	NO	Front and Back faces of the internal solid radiator (down)
tub-2_horizontal	Wall	Heat Flux	NO	Front and Back faces of the internal solid radiator (up)
tub-1_horizontal_rad	Wall	Heat Flux	NO	Top and Bottom faces of the internal solid radiator (down)
tub-2_horizontal_rad	Wall	Heat Flux	NO	Top and Bottom faces of the internal solid radiator (up)
tub-1_vertical	Wall	Heat Flux	NO	Front and Back faces of the internal solid radiator (left)
tub-2_vertical	Wall	Heat Flux	NO	Front and Back faces of the internal solid radiator (middle)
tub-3_vertical	Wall	Heat Flux	NO	Front and Back faces of the internal solid radiator (right)
tub-1_vertical_rad	Wall	Heat Flux	NO	Left and Right faces of the internal solid radiator (left)
tub-2_vertical_rad	Wall	Heat Flux	NO	Left and Right faces of the internal solid radiator (middle)
tub-3_vertical_rad	Wall	Heat Flux	NO	Left and Right faces of the internal solid radiator (right)
radiator_interior	Interior	None		Interior face in the radiator (in contact with solid)
rad_int_front	Interior	None		Radiator front face
rad_int_back	Interior	None		Radiator back face
frame_interior	Interior	None		Interior faces of the frame
tunel_interior	Interior	None		Interior faces of the tunel
tunel_top	Wall	Heat Flux	NO	Tunel top face
tunel_bottom	Wall	Heat Flux	NO	Tunel bottom face
tunel_left	Wall	Heat Flux	NO	Tunel left face
tunel_right	Wall	Heat Flux	NO	Tunel right face
tunel_outlet	Pressure Outlet	Gauge Pressure Backflow Temp. Back Flow Turb. Back Flow Hydr.	0 351 10% 550	Duct outlet
tunel_inlet	Velocity Inlet	Vel. Magnitude Temperature Turbulence Intensity Hydr. Diameter	20 300 10% 550	Duct inlet

Fluid Zones	***Type***	***Options***	***Values***	***Function***
rad_air	Fluid	Laminar Zone Porous Zone	YES YES	Air inside the radiator
frame	Solid	Source Terms Fixed Values	NO NO	Frame solid
rad_solid	Solid	Source Terms Fixed Values	NO NO	Solid parts of the radiator
tunel_air	Fluid	Laminar Zone Porous Zone	NO NO	Air through the tunel

Tabla B.4: *Características del Modelo - 4*

3. ANEXO C: PROPIEDADES DE LOS MATERIALES UTILIZADOS EN LAS SIMULACIONES

En este Anexo se trata de presentar los valores de las propiedades que han tomado los materiales utilizados en las simulaciones. En el caso concreto del proyecto se han utilizado dos tipos de materiales. El aire como Fluido y como parte sólida el Aluminio.

Air

Initial Values		
Velocity	9,57000	m/s
Area	0,13376	m2
Density	1,06350	Kg/m3
Cp	1,00700	KJ/KgK
Viscosity	2,0033E-05	Kg/ms
Term. Cond.	0,02780	W/mK
Flujo	1,36137	kg/s
	1,28008	m3/s
T in	310,93000	K
Tout	351,76000	K

Aluminium

Initial Values		
Density	2700	Kg/m3
Cp	899	KJ/KgK
Therm. Cond.	229	W/mK

Tabla C.1: *Características de los Materiales empleados en las simulaciones*

4. ANEXO D: REPRESENTACIONES DEL FLUJO DEL MODELO4 – MODIFICADO

En el siguiente Anexo se presentan aquellas representaciones que no se han expuesto en la memoria del proyecto y que pueden ser de ayuda a la hora de comprender o hacerse una idea del flujo de aire que pasa a través del radiador.

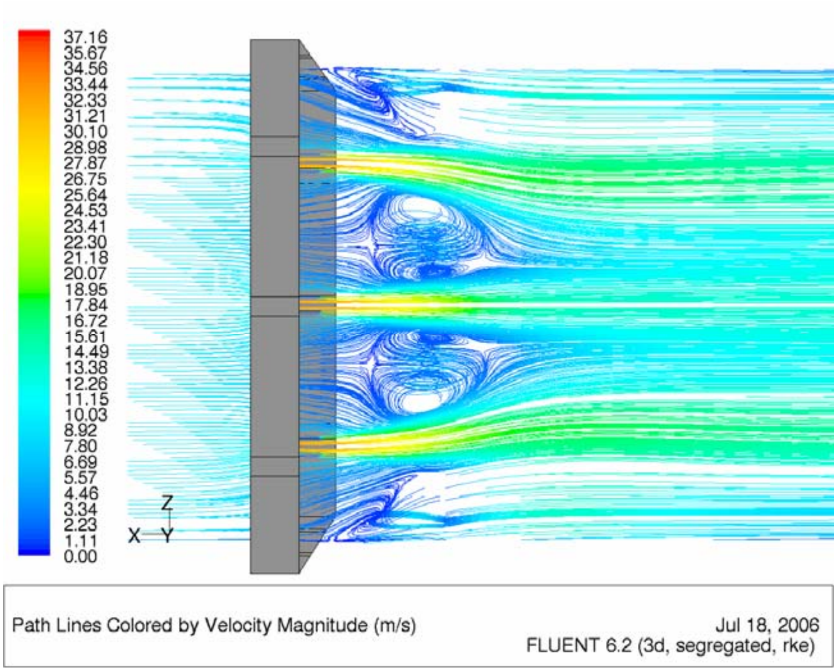


Fig. D.1: *Vista superior del Modelo. Visualización de las PathLines de Velocidad en el plano Z=0*

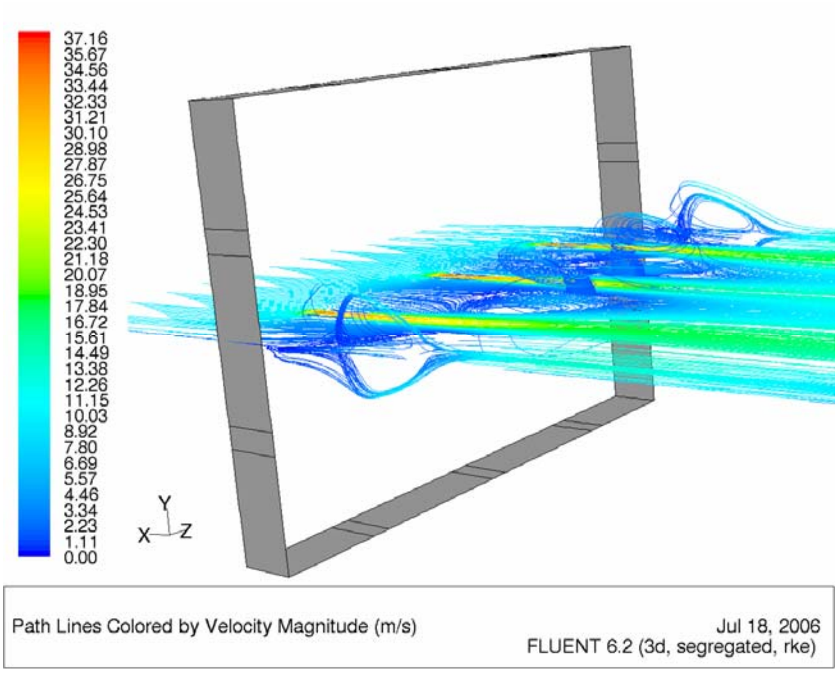


Fig. D.2: *Vista en prespectiva del Modelo. Visualización de las PathLines de Velocidad en el plano Z=0*

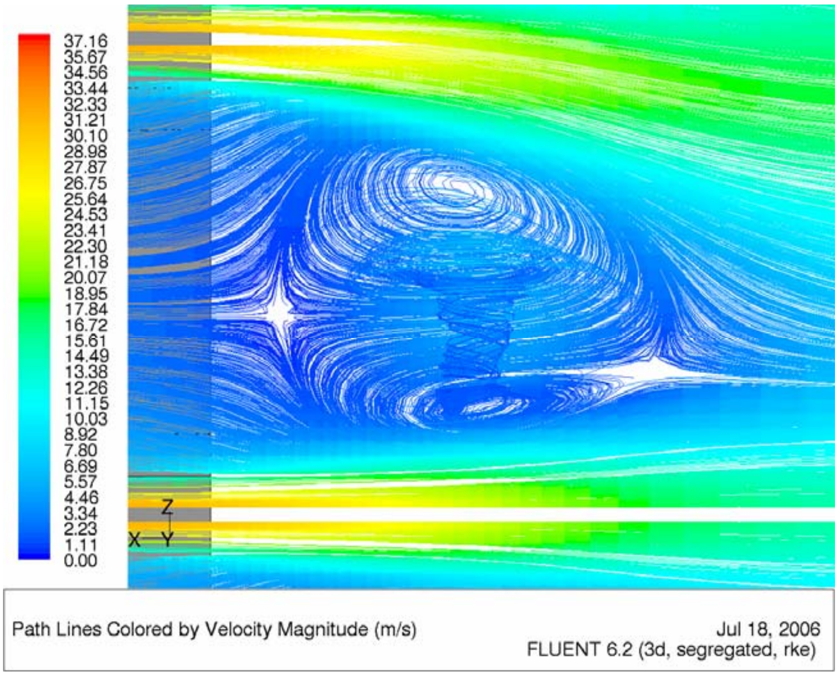


Fig. D.3: *Representación de la turbulencia en la parte posterior del Modelo. Visualización de las PathLines de Velocidad en el plano Z=0*

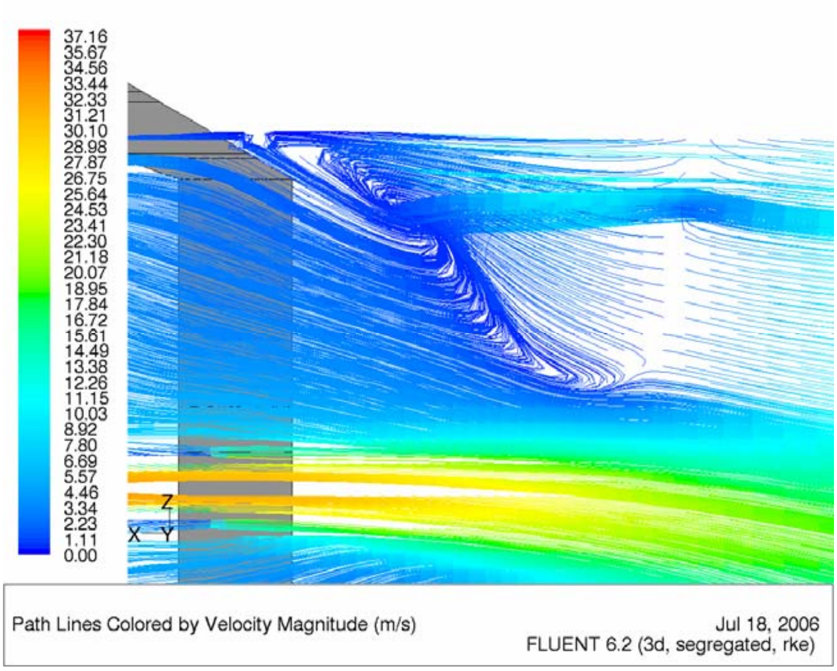


Fig. D.4: *Representación de la turbulencia cerca de las paredes. Visualización de las PathLines de Velocidad en el plano Z=0*

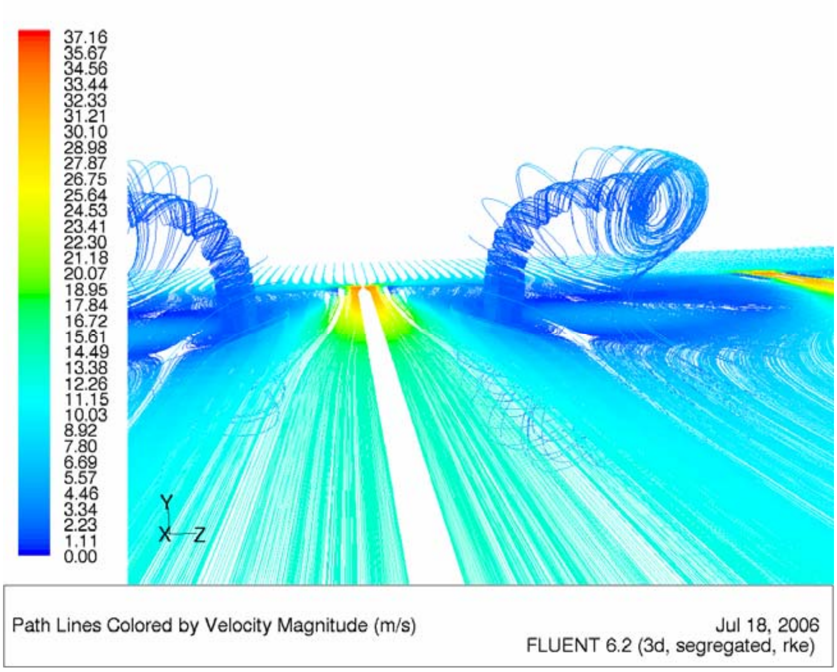


Fig. D.5: *Vista posterior de las turbulencias. Visualización de las PathLines de Velocidad en el plano Z=0*

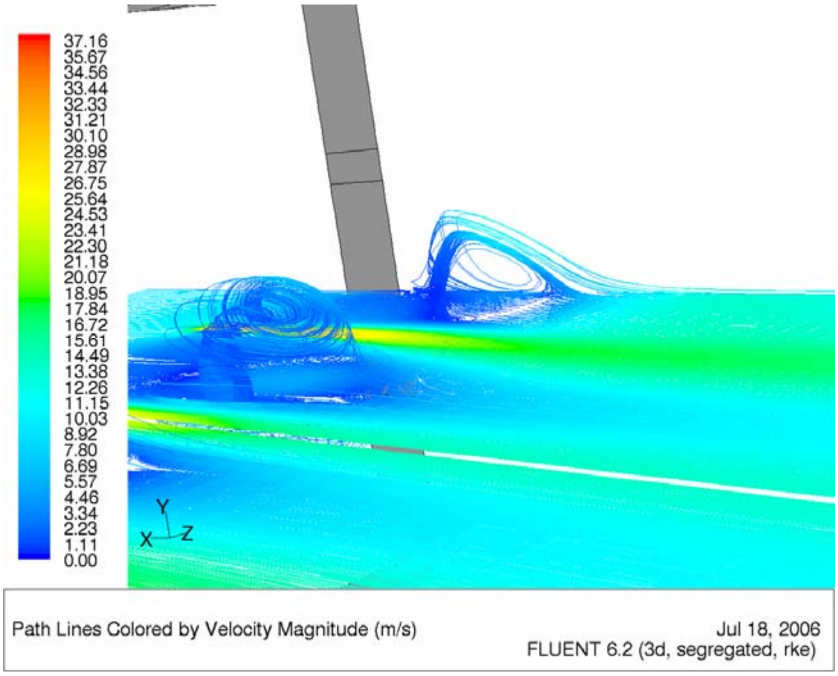


Fig. D.6: *Vista posterior de las turbulencias. Visualización de las PathLines de Velocidad en el plano Z=0*

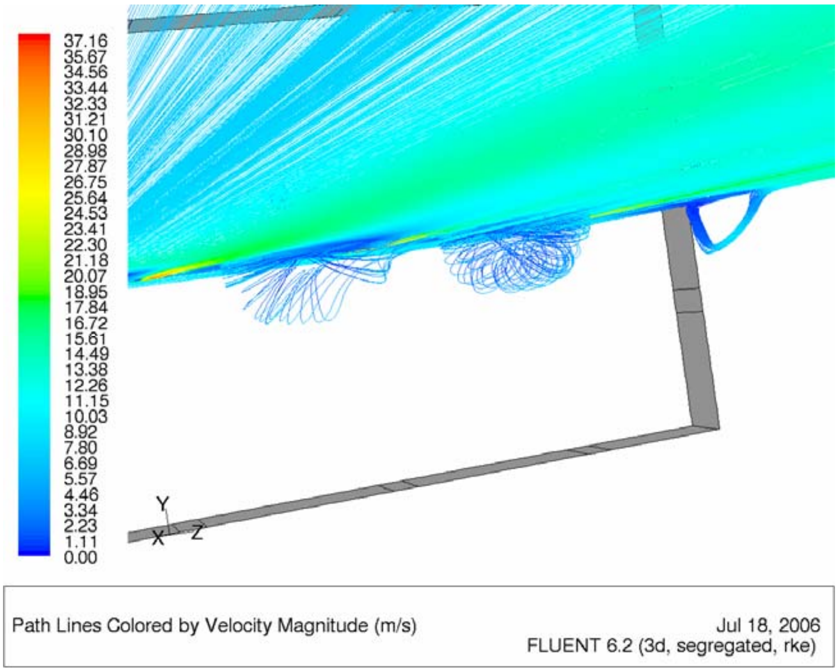


Fig. D.7: *Vista posterior de las turbulencias. Visualización de las PathLines de Velocidad en el plano Z=0*

5. ANEXO E: CONFIGURACIÓN DE LOS MODELOS EN FLUENT

En este anexo se presentan mediante tablas las configuraciones empleadas en el programa de CFD, Fluent, a la hora de simularse los modelos. En ellas se puede ver las acarcteristicas principales de la configuración.

Modelo – 1

MODEL - 1

REAL CASE

INLET	*Velocity*	9,5700	m/s
	G. Pressure	-	Pa
	Mass Flow Inlet	1,4113	Kg/s
OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Radiator INLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Pressure Drop	Δp	aprox.	1.743,0000	Pa
Dynamic Pressure	Pd (outlet)	aprox.	190,0000	Pa
Blockage Factor	k	aprox.	9,0000	-

Air gain Temperature	ΔT	40,8200	K
T in (air)	T in	310,9400	K
T out (air)	T out	351,7600	K

HEAT CONFIGURATION

Type	Radiator			
Walls	*Front*	P - Loss	36	Pa
		Temp.	370	K
		h	4260	1/s

SIMULATION RESULTS

INLET	*Velocity*	9,5700	m/s
	G. Pressure	1.758,3817	Pa
	Mass Flow Inlet		Kg/s
OUTLET	*Velocity*		m/s
	G. Pressure	0,0000	Pa

Radiator INLET	*Velocity*		m/s
	G. Pressure	1.757,4112	Pa
Radiator OUTLET	*Velocity*		m/s
	G. Pressure	3,7696	Pa

Pressure Drop	Δp	1.753,6416	Pa
Dynamic Pressure	Pd (outlet)	48,8847	Pa
Blockage Factor	k	**35,8730**	-
Real BF	k (real)	**9,0000**	-

Temperatures	*Top*	327,92	K
	Bottom	327,93	K
	Left	327,92	K
	Right	327,92	K
	Inlet	310,94	K
	Outlet	327,47	K
	Rad_front	318,63	K
	Rad_back	328,30	K
			K
			K

Air gain Temperature 1	**16,53**	K
Air gain Temperature 2	9,68	K

Modelo – 2

MODEL - 2

REAL CASE			
INLET	*Velocity*	9,5700	m/s
	G. Pressure	-	Pa
	Mass Flow Inlet	1,4113	Kg/s
OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator INLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Pressure Drop	Δp	aprox. 1.743,0000	Pa
Dynamic Pressure	Pd (outlet)	aprox. 190,0000	Pa
Blockage Factor	k	aprox. 9,0000	-
Air gain Temperature	ΔT	40,8200	K
T in (air)	T in	310,9400	K
T out (air)	T out	351,7600	K

HEAT CONFIGURATION

Type	Radiator			
Walls	*Rad-1*	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s
	Rad-2	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s
	Rad-3	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s
	Rad-4	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s

Type	Temperature		
Walls	*Top*	367,790	K
	Bottom	350,000	K
	Left	360,000	K
	Right	360,000	K

SIMULATION RESULTS			
INLET	*Velocity*	9,5700	m/s
	G. Pressure	95,2472	Pa
	Mass Flow Inlet	1,4532	Kg/s
OUTLET	*Velocity*	9,7800	m/s
	G. Pressure	0,0000	Pa
Radiator INLET	*Velocity*	10,8306	m/s
	G. Pressure	66,6135	Pa
Radiator OUTLET	*Velocity*	10,1506	m/s
	G. Pressure	-50,1925	Pa
Pressure Drop	Δp	116,8060	Pa
Dynamic Pressure	Pd (outlet)	62,2799	Pa
Blockage Factor	k	**1,8755**	-
Real BF	k (real)	9,0000	-
Temperatures	*Top*	367,79	K
	Bottom	349,93	K
	Left	359,72	K
	Right	359,72	K
	Inlet	310,94	K
	Outlet	330,02	K
	Rad_front	329,17	K
	Rad_back	341,00	K
			K
			K

Air gain Temperature 1	**19,08**	K
Air gain Temperature 2	**30,06**	K

Modelo – 3

MODEL - 3

REAL CASE

INLET	*Velocity*	9,5700	m/s
	G. Pressure	-	Pa
	Mass Flow Inlet	1,4113	Kg/s
OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator INLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Pressure Drop	Δp	aprox. 1.743,0000	Pa
Dynamic Pressure	Pd (outlet)	aprox. 190,0000	Pa
Blockage Factor	k	aprox. 9,0000	-

Air gain Temperature	ΔT	40,8200	K
T in (air)	T in	310,9400	K
T out (air)	T out	351,7600	K

HEAT CONFIGURATION

Type	Radiator			
Walls	*Rad-1*	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s
	Rad-2	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s
	Rad-3	P - Loss	36	Pa
		Temp.	380	K
		h	4260	1/s

Type	Temperature		
Walls	*Top*	370,000	K
	Bottom	350,000	K
	Left	360,000	K
	Right	360,000	K
	Solid	370,000	K

SIMULATION RESULTS

INLET	*Velocity*	9,5700	m/s
	G. Pressure	2.397,7668	Pa
	Mass Flow Inlet	1,4531	Kg/s
OUTLET	*Velocity*	9,9500	m/s
	G. Pressure	0,0000	Pa
Radiator INLET	*Velocity*	9,5994	m/s
	G. Pressure	2.397,2994	Pa
Radiator OUTLET	*Velocity*	10,2410	m/s
	G. Pressure	-9,7400	Pa

Pressure Drop	Δp	2.407,0394	Pa
Dynamic Pressure	Pd (outlet)	61,9300	Pa
Blockage Factor	k	**38,8671**	-
Real BF	k (real)	9,0000	-

Temperatures	*Top*	367,50	K
	Bottom	348,56	K
	Left	357,29	K
	Right	357,29	K
	Inlet	310,94	K
	Outlet	328,81	K
	Rad_front	311..374	K
	Rad_back	328,73	K
			K
			K

Air gain Temperature 1	**17,87**	K
Air gain Temperature 2	**17,79**	K

Modelo – 4

MODEL - 4

REAL CASE

INLET	*Velocity*	9,5700	m/s
	G. Pressure	-	Pa
	Mass Flow Inlet	1,4113	Kg/s
OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Radiator INLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Pressure Drop	Δp	aprox. 1.743,0000	Pa
Dynamic Pressure	Pd (outlet)	aprox. 190,0000	Pa
Blockage Factor	k	aprox. 9,0000	-

Air gain Temperature	ΔT	40,8200	K
T in (air)	T in	310,9400	K
T out (air)	T out	351,7600	K

HEAT CONFIGURATION

Type	Radiator			
Walls	*Front*	P - Loss	60	Pa
		Temp.	380	K
		h	12000	1/s

SIMULATION RESULTS

INLET	*Velocity*	9,5700	m/s
	G. Pressure	693,4470	Pa
	Mass Flow Inlet	4,1153	Kg/s
OUTLET	*Velocity*	10,1391	m/s
	G. Pressure	0,0000	Pa

Radiator INLET	*Velocity*	11,2866	m/s
	G. Pressure	663,8953	Pa
Radiator OUTLET	*Velocity*	10,3093	m/s
	G. Pressure	-118,2647	Pa

Pressure Drop	Δp	782,1601	Pa
Dynamic Pressure	Pd (outlet)	123,2512	Pa
Blockage Factor	k	**6,3461**	-
Real BF	k (real)	9,0000	-

Temperatures	*Top*	352,84	K
	Bottom	352,84	K
	Left	352,95	K
	Right	352,95	K
	Inlet	300,00	K
	Outlet	321,53	K
	Rad_front	301,73	K
	Rad_back	343,51	K
			K
			K

Air gain Temperature 1	21,53	K
Air gain Temperature 2	**43,51**	K

Modelo4 – Modificado

MODEL4 - Modified

REAL CASE

INLET	*Velocity*	9,5700	m/s
	G. Pressure	-	Pa
	Mass Flow Inlet	1,4113	Kg/s
OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator INLET	*Velocity*	-	m/s
	G. Pressure	-	Pa
Radiator OUTLET	*Velocity*	-	m/s
	G. Pressure	-	Pa

Pressure Drop	Δp	aprox.	1.743,0000	Pa
Dynamic Pressure	Pd (outlet)	aprox.	190,0000	Pa
Blockage Factor	k	aprox.	9,0000	-

Air gain Temperature	ΔT	40,8200	K
T in (air)	T in	310,9400	K
T out (air)	T out	351,7600	K

HEAT CONFIGURATION of M0-1_mod2

Type	Radiator			
Walls	*Front*	P - Loss	65	Pa
		Temp.	380	K
		h	13500	1/s

HEAT CONFIGURATION of M0-1_mod3

Type	Radiator			
Walls	*Front*	P - Loss	65	-
		Temp.	**385**	K
		h	13500	1/s

SIMULATION RESULTS

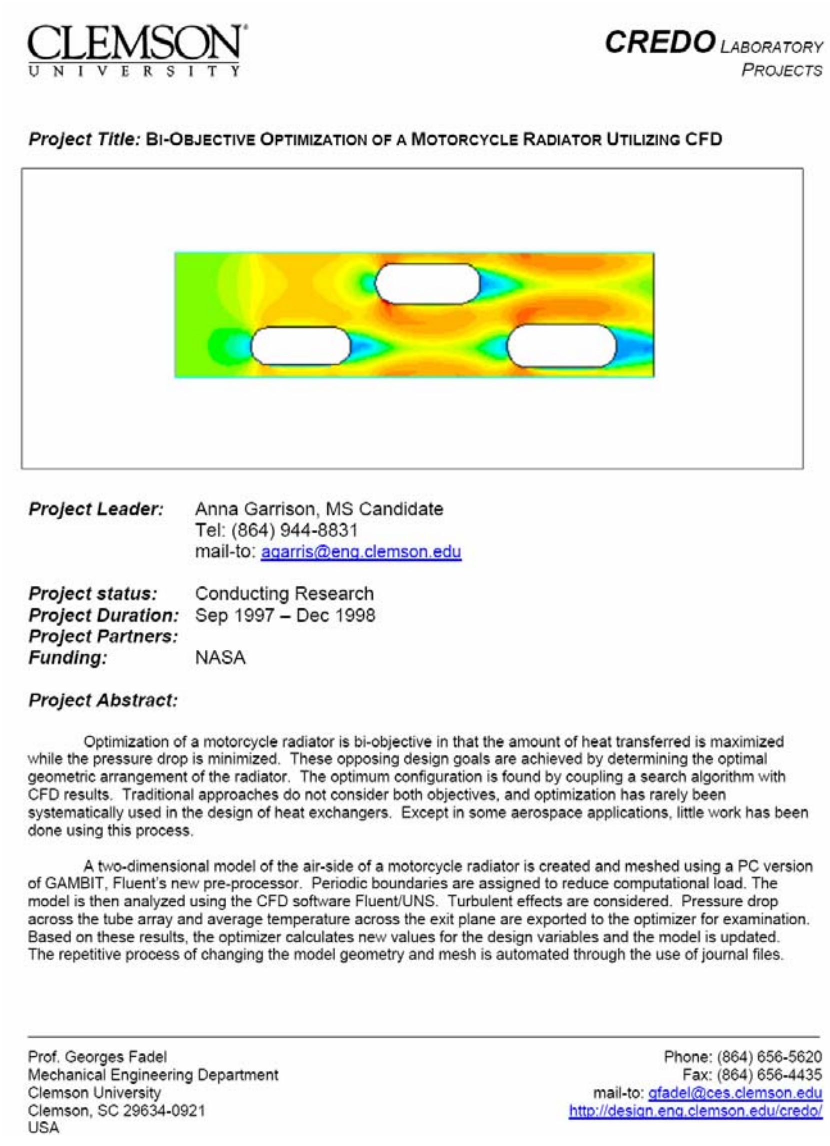
		Model4 - Mod	
INLET	*Velocity*	9,5700	m/s
	G. Pressure	691,8860	Pa
	Mass Flow Inlet	1,4531	Kg/s
OUTLET	*Velocity*	10,0892	m/s
	G. Pressure	0,0000	Pa
Radiator INLET	*Velocity*	11,3498	m/s
	G. Pressure	662,1960	Pa
Radiator OUTLET	*Velocity*	10,2659	m/s
	G. Pressure	-107,7419	Pa
Pressure Drop	Δp	769,9378	Pa
Dynamic Pressure	Pd (outlet)	84,9961	Pa
Blockage Factor	k	**9,0585**	-
Real BF	k (real)	**9,0000**	-
Temperatures	*Top*	362,46	K
	Bottom	362,46	K
	Left	362,57	K
	Right	362,57	K
	Inlet	310,97	K
	Outlet	331,53	K
	Rad_front	312,74	K
	Rad_back	353,32	K
			K
			K

Air gain Temperature 1	20,56	K
Air gain Temperature 2	**40,58**	K

6. ANEXO F: ARTÍCULOS CONSULTADOS EN EL PROYECTO

En el proyecto se han consultado artículos de diferentes personas que por su dificultad a la hora de poderse encontrar en la red (Internet) se ha decidido ponerlos en el anexo, ya que de esta forma será mucho más cómodo para las personas interesadas en el proyecto su consulta.

Artículo 1: GARRISON A., *Bi-Objective Optimization of a Motorcycle Radiator Utilizing CFD*.



CLEMSON
UNIVERSITY

CREDO LABORATORY
PROJECTS

Project Title: BI-OBJECTIVE OPTIMIZATION OF A MOTORCYCLE RADIATOR UTILIZING CFD

Project Leader: Anna Garrison, MS Candidate
Tel: (864) 944-8831
mail-to: agarris@eng.clemson.edu

Project status: Conducting Research
Project Duration: Sep 1997 – Dec 1998
Project Partners:
Funding: NASA

Project Abstract:

Optimization of a motorcycle radiator is bi-objective in that the amount of heat transferred is maximized while the pressure drop is minimized. These opposing design goals are achieved by determining the optimal geometric arrangement of the radiator. The optimum configuration is found by coupling a search algorithm with CFD results. Traditional approaches do not consider both objectives, and optimization has rarely been systematically used in the design of heat exchangers. Except in some aerospace applications, little work has been done using this process.

A two-dimensional model of the air-side of a motorcycle radiator is created and meshed using a PC version of GAMBIT, Fluent's new pre-processor. Periodic boundaries are assigned to reduce computational load. The model is then analyzed using the CFD software Fluent/UNS. Turbulent effects are considered. Pressure drop across the tube array and average temperature across the exit plane are exported to the optimizer for examination. Based on these results, the optimizer calculates new values for the design variables and the model is updated. The repetitive process of changing the model geometry and mesh is automated through the use of journal files.

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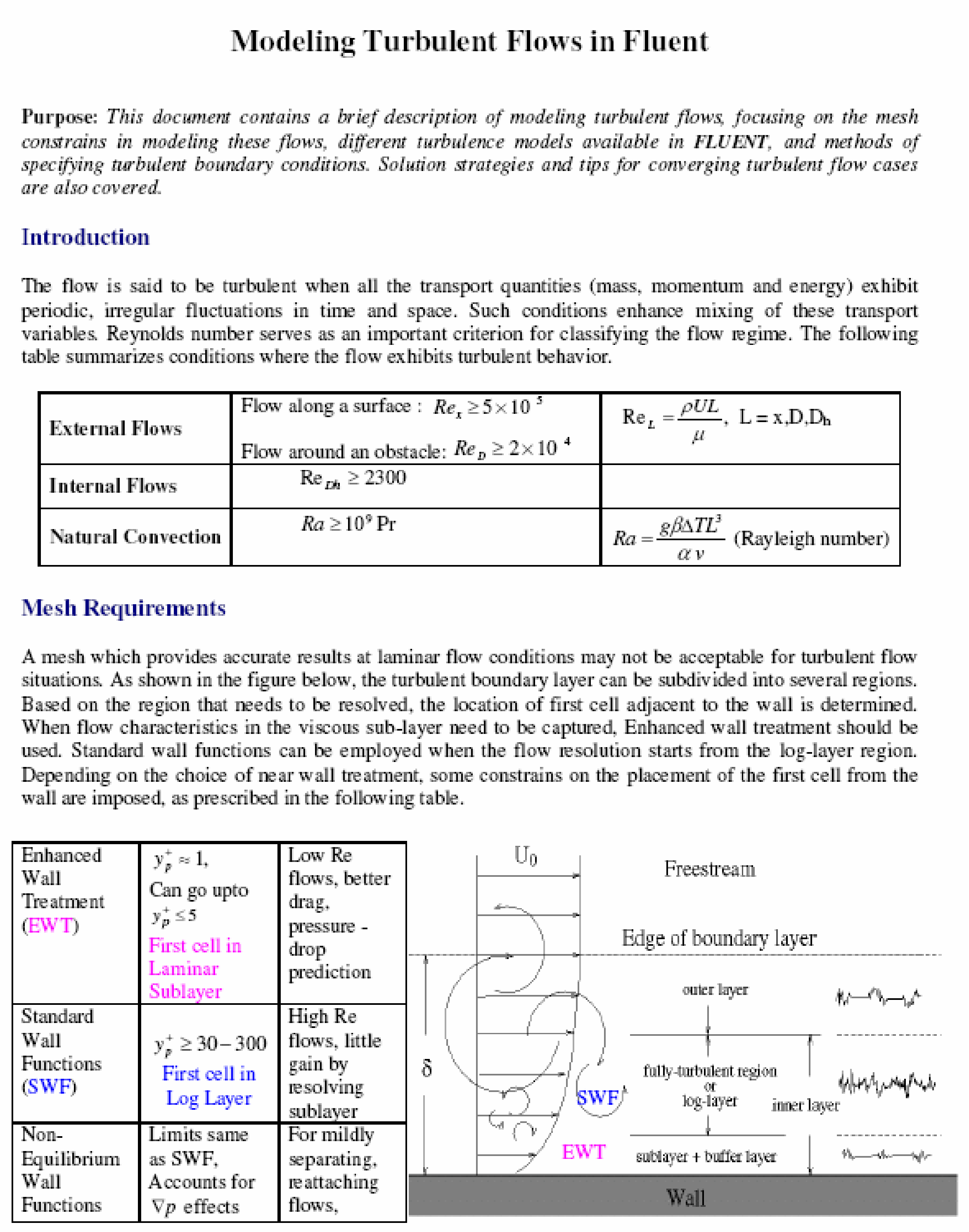
Artículo 2: CHILKA A., KULKARNI A.; *Modeling Turbulent Flows in Fluent*. Pagina oficial de Fluent.



Modeling Turbulent Flows in Fluent

Purpose: *This document contains a brief description of modeling turbulent flows, focusing on the mesh constrains in modeling these flows, different turbulence models available in **FLUENT**, and methods of specifying turbulent boundary conditions. Solution strategies and tips for converging turbulent flow cases are also covered.*

Introduction

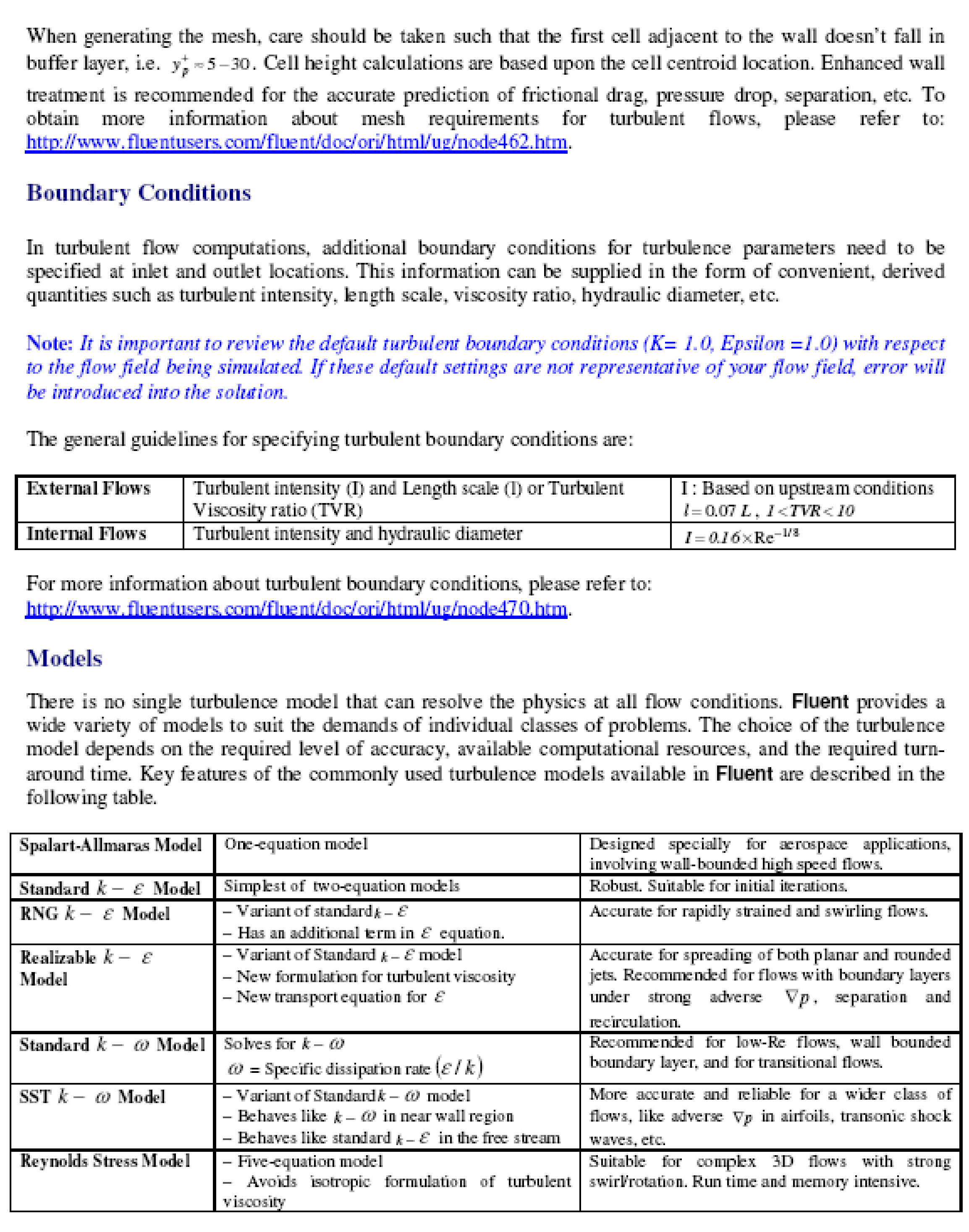
The flow is said to be turbulent when all the transport quantities (mass, momentum and energy) exhibit periodic, irregular fluctuations in time and space. Such conditions enhance mixing of these transport variables. Reynolds number serves as an important criterion for classifying the flow regime. The following table summarizes conditions where the flow exhibits turbulent behavior.

External Flows	Flow along a surface : $Re_x \ge 5\times 10^5$ Flow around an obstacle: $Re_D \ge 2\times 10^4$	$\mathrm{Re}_L = \frac{\rho UL}{\mu}$, $L = x, D, D_h$
Internal Flows	$\mathrm{Re}_{Dh} \ge 2300$	
Natural Convection	$Ra \ge 10^9 \Pr$	$Ra = \frac{g\beta\Delta TL^3}{\alpha\nu}$ (Rayleigh number)

Mesh Requirements

A mesh which provides accurate results at laminar flow conditions may not be acceptable for turbulent flow situations. As shown in the figure below, the turbulent boundary layer can be subdivided into several regions. Based on the region that needs to be resolved, the location of first cell adjacent to the wall is determined. When flow characteristics in the viscous sub-layer need to be captured, Enhanced wall treatment should be used. Standard wall functions can be employed when the flow resolution starts from the log-layer region. Depending on the choice of near wall treatment, some constrains on the placement of the first cell from the wall are imposed, as prescribed in the following table.

Enhanced Wall Treatment (EWT)	$y_p^+ \approx 1$, Can go upto $y_p^+ \le 5$ First cell in Laminar Sublayer	Low Re flows, better drag, pressure - drop prediction
Standard Wall Functions (SWF)	$y_p^+ \ge 30-300$ First cell in Log Layer	High Re flows, little gain by resolving sublayer
Non-Equilibrium Wall Functions	Limits same as SWF, Accounts for ∇p effects	For mildly separating, reattaching flows,



When generating the mesh, care should be taken such that the first cell adjacent to the wall doesn't fall in buffer layer, i.e. $y_p^+ \approx 5-30$. Cell height calculations are based upon the cell centroid location. Enhanced wall treatment is recommended for the accurate prediction of frictional drag, pressure drop, separation, etc. To obtain more information about mesh requirements for turbulent flows, please refer to: http://www.fluentusers.com/fluent/doc/ori/html/ug/node462.htm.

Boundary Conditions

In turbulent flow computations, additional boundary conditions for turbulence parameters need to be specified at inlet and outlet locations. This information can be supplied in the form of convenient, derived quantities such as turbulent intensity, length scale, viscosity ratio, hydraulic diameter, etc.

Note: *It is important to review the default turbulent boundary conditions (K= 1.0, Epsilon =1.0) with respect to the flow field being simulated. If these default settings are not representative of your flow field, error will be introduced into the solution.*

The general guidelines for specifying turbulent boundary conditions are:

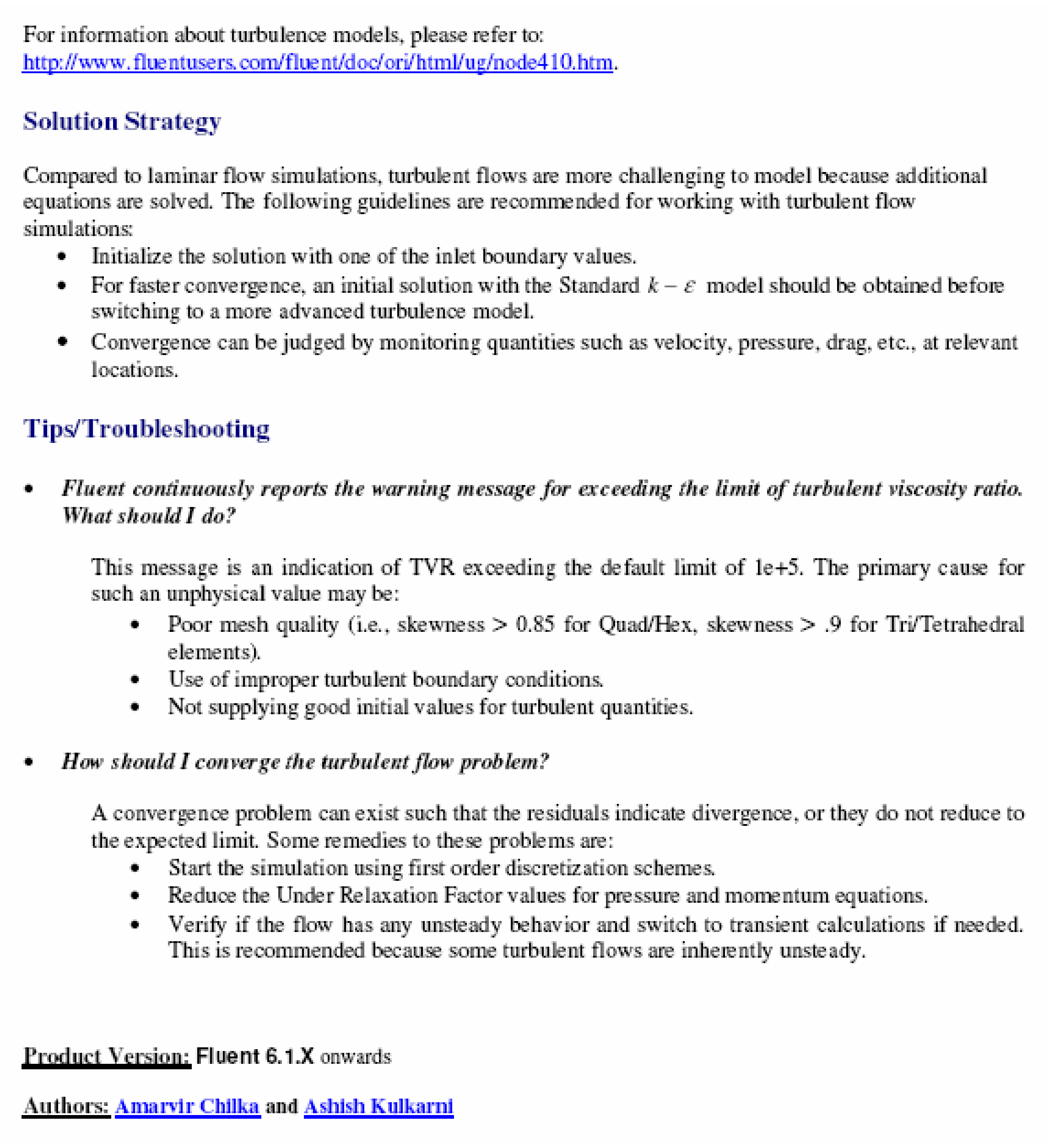
External Flows	Turbulent intensity (I) and Length scale (l) or Turbulent Viscosity ratio (TVR)	I : Based on upstream conditions $l = 0.07\ L$, $1 < TVR < 10$
Internal Flows	Turbulent intensity and hydraulic diameter	$I = 0.16 \times \mathrm{Re}^{-1/8}$

For more information about turbulent boundary conditions, please refer to: http://www.fluentusers.com/fluent/doc/ori/html/ug/node470.htm.

Models

There is no single turbulence model that can resolve the physics at all flow conditions. **Fluent** provides a wide variety of models to suit the demands of individual classes of problems. The choice of the turbulence model depends on the required level of accuracy, available computational resources, and the required turn-around time. Key features of the commonly used turbulence models available in **Fluent** are described in the following table.

Spalart-Allmaras Model	One-equation model	Designed specially for aerospace applications, involving wall-bounded high speed flows.
Standard $k-\varepsilon$ Model	Simplest of two-equation models	Robust. Suitable for initial iterations.
RNG $k-\varepsilon$ Model	– Variant of standard $k-\varepsilon$ – Has an additional term in ε equation.	Accurate for rapidly strained and swirling flows.
Realizable $k-\varepsilon$ Model	– Variant of Standard $k-\varepsilon$ model – New formulation for turbulent viscosity – New transport equation for ε	Accurate for spreading of both planar and rounded jets. Recommended for flows with boundary layers under strong adverse ∇p, separation and recirculation.
Standard $k-\omega$ Model	Solves for $k-\omega$ ω = Specific dissipation rate (ε / k)	Recommended for low-Re flows, wall bounded boundary layer, and for transitional flows.
SST $k-\omega$ Model	– Variant of Standard $k-\omega$ model – Behaves like $k-\omega$ in near wall region – Behaves like standard $k-\varepsilon$ in the free stream	More accurate and reliable for a wider class of flows, like adverse ∇p in airfoils, transonic shock waves, etc.
Reynolds Stress Model	– Five-equation model – Avoids isotropic formulation of turbulent viscosity	Suitable for complex 3D flows with strong swirl/rotation. Run time and memory intensive.



For information about turbulence models, please refer to:
http://www.fluentusers.com/fluent/doc/ori/html/ug/node410.htm.

Solution Strategy

Compared to laminar flow simulations, turbulent flows are more challenging to model because additional equations are solved. The following guidelines are recommended for working with turbulent flow simulations:

- Initialize the solution with one of the inlet boundary values.
- For faster convergence, an initial solution with the Standard $k-\varepsilon$ model should be obtained before switching to a more advanced turbulence model.
- Convergence can be judged by monitoring quantities such as velocity, pressure, drag, etc., at relevant locations.

Tips/Troubleshooting

- ***Fluent continuously reports the warning message for exceeding the limit of turbulent viscosity ratio. What should I do?***

  This message is an indication of TVR exceeding the default limit of 1e+5. The primary cause for such an unphysical value may be:
  - Poor mesh quality (i.e., skewness > 0.85 for Quad/Hex, skewness > .9 for Tri/Tetrahedral elements).
  - Use of improper turbulent boundary conditions.
  - Not supplying good initial values for turbulent quantities.

- ***How should I converge the turbulent flow problem?***

  A convergence problem can exist such that the residuals indicate divergence, or they do not reduce to the expected limit. Some remedies to these problems are:
  - Start the simulation using first order discretization schemes.
  - Reduce the Under Relaxation Factor values for pressure and momentum equations.
  - Verify if the flow has any unsteady behavior and switch to transient calculations if needed. This is recommended because some turbulent flows are inherently unsteady.

Product Version: **Fluent 6.1.X** onwards

Authors: **Amarvir Chilka** **and** **Ashish Kulkarni**