Computational Fluid Dynamics in Combustion

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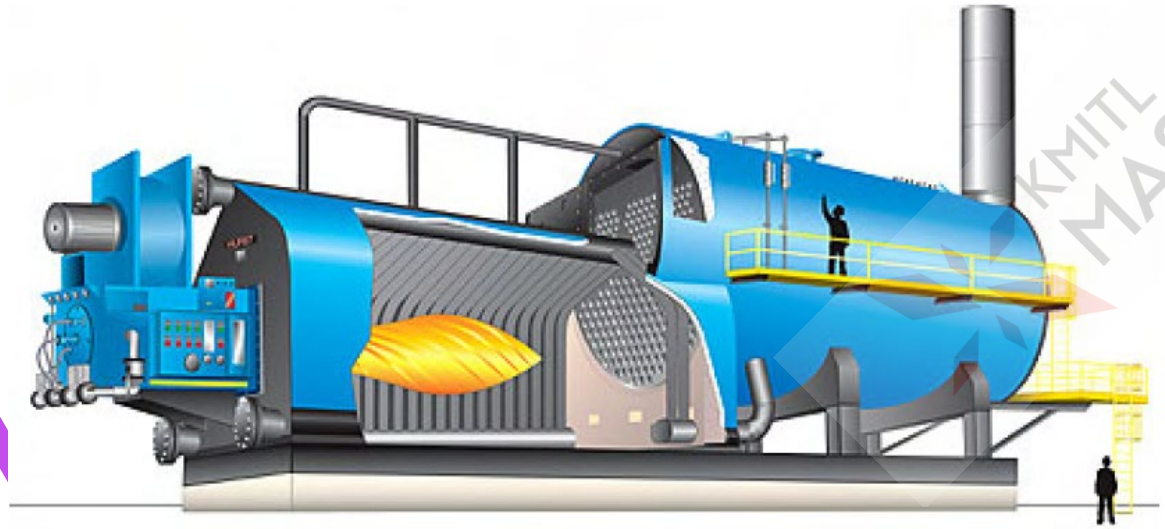
Backgrounds

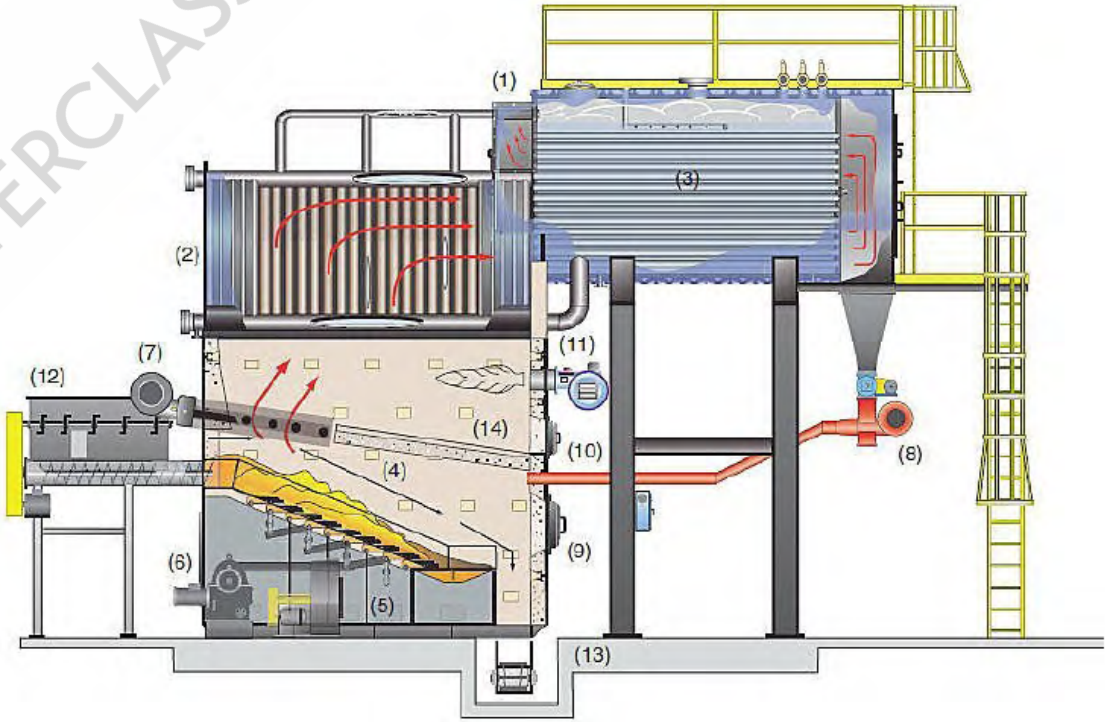
- Boiler, How it works ? - YouTube
- Steam Boiler feedWater and Steam Cycles - Controlled Circulation - YouTube
- How Biomass works - YouTube

Boilers

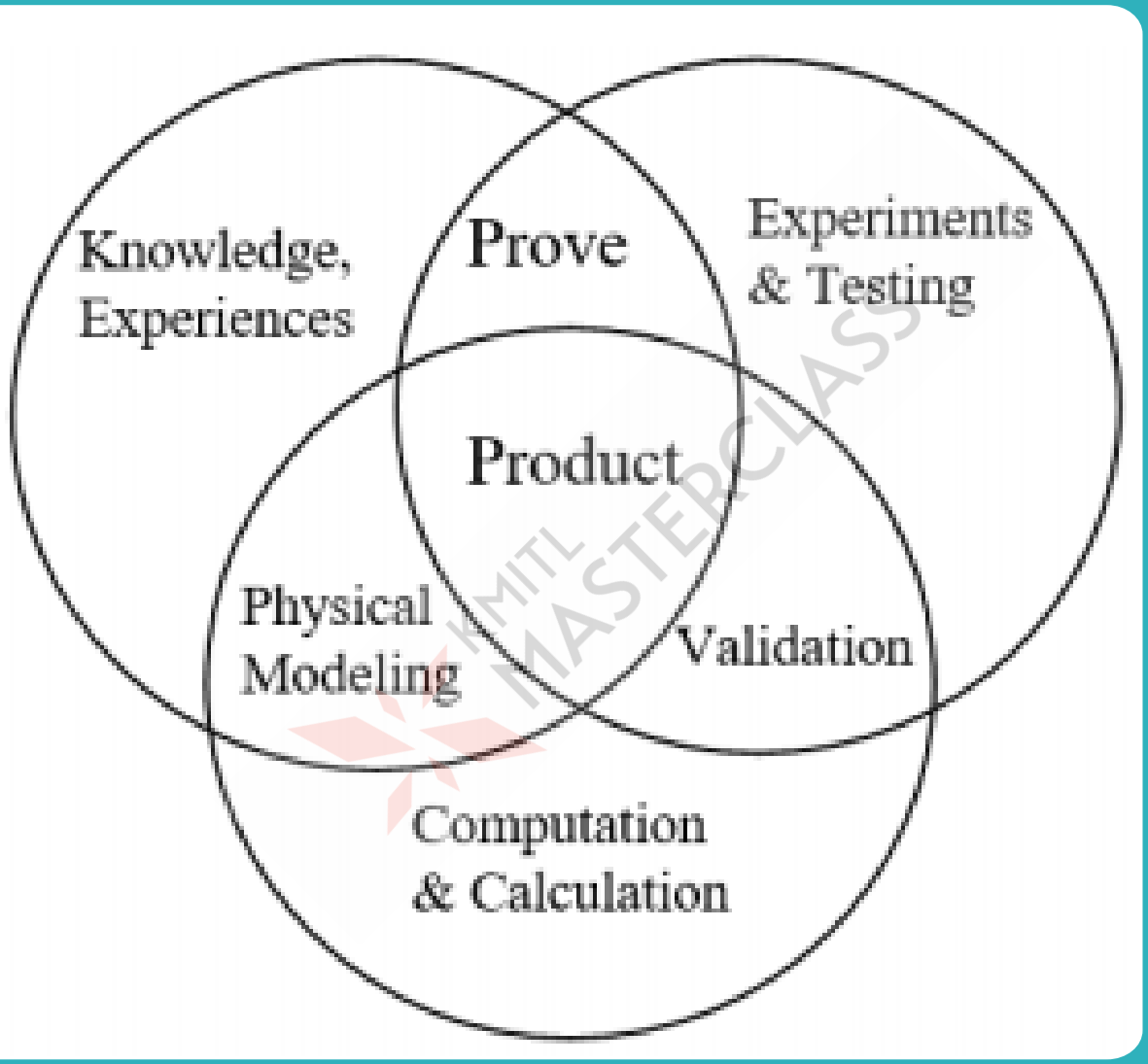
Oil or gas fired furnace



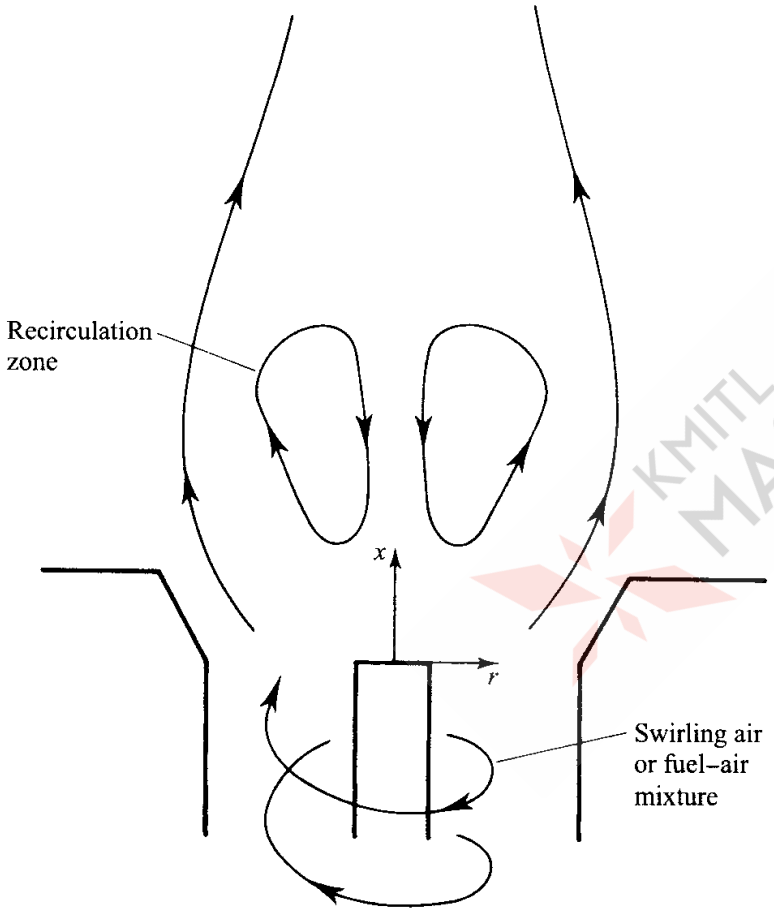
solid fuel fired furnace

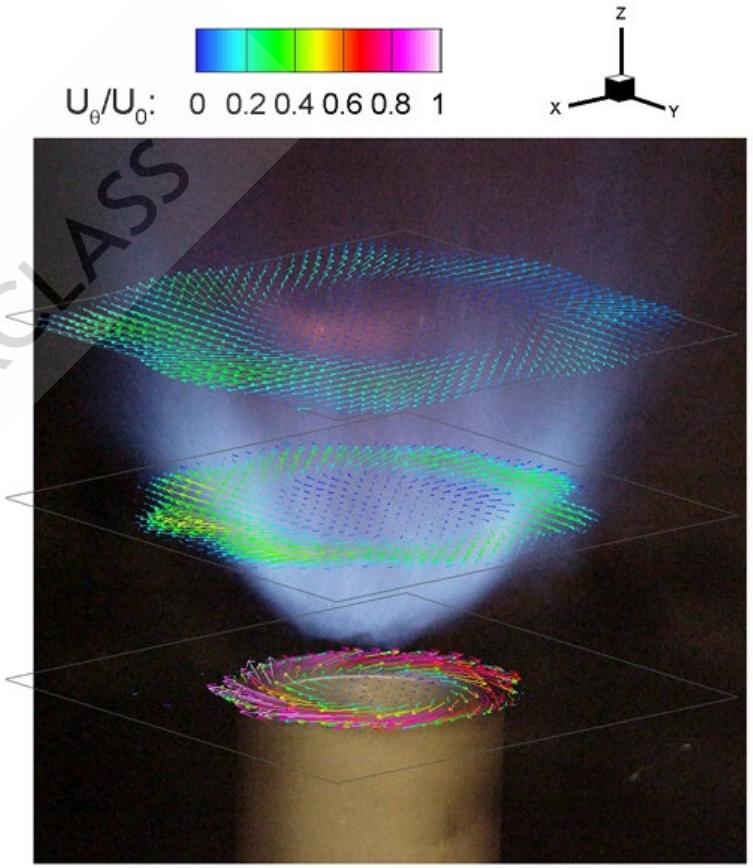


How a Firetube Boiler Works - YouTube

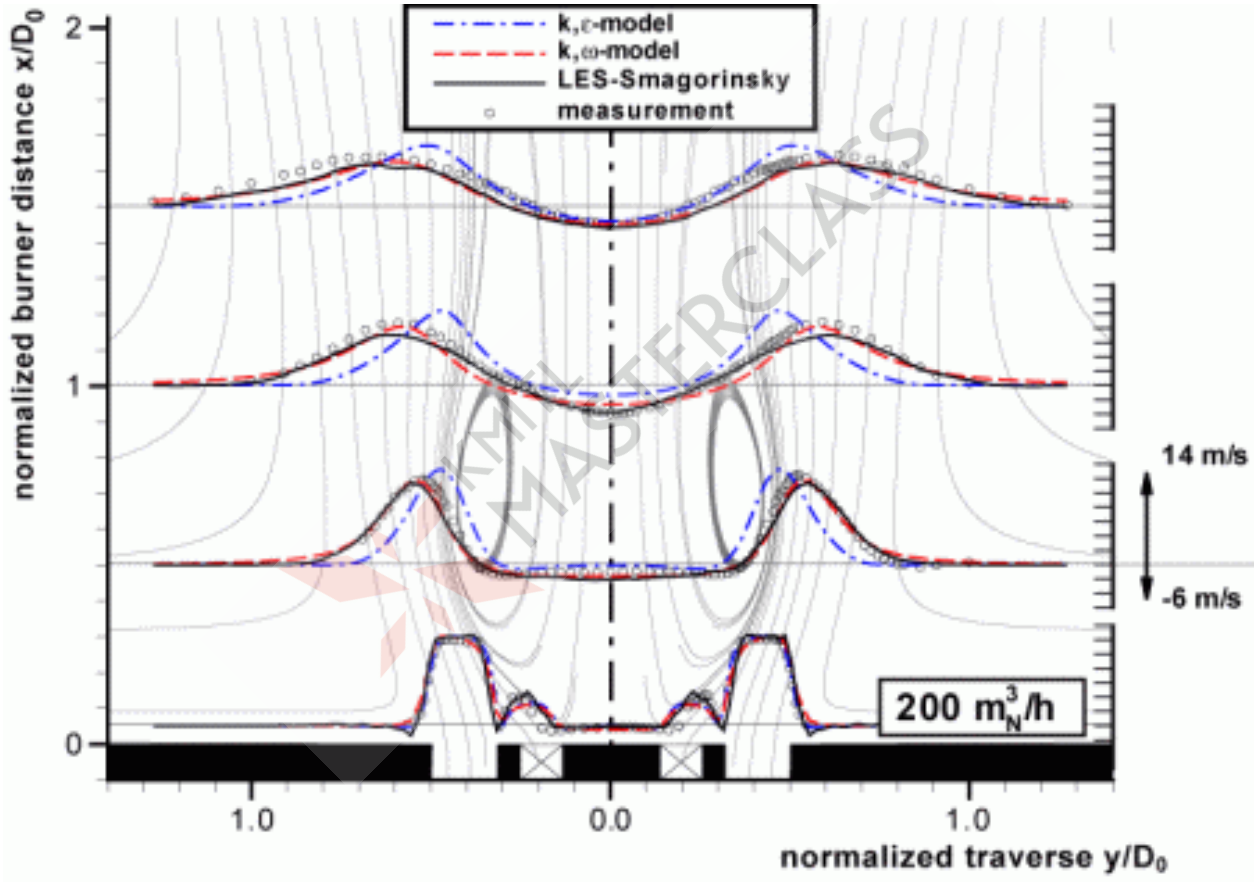

Knowledge,
Experiences
Prove
Experiments
& Testing
Product
Physical
Modeling
Validation
Computation
& Calculation

Swirl stabilized flame





Streamline of swirl flow



ffle_swirlflame_anim.gif

Effect of swirl on flame length

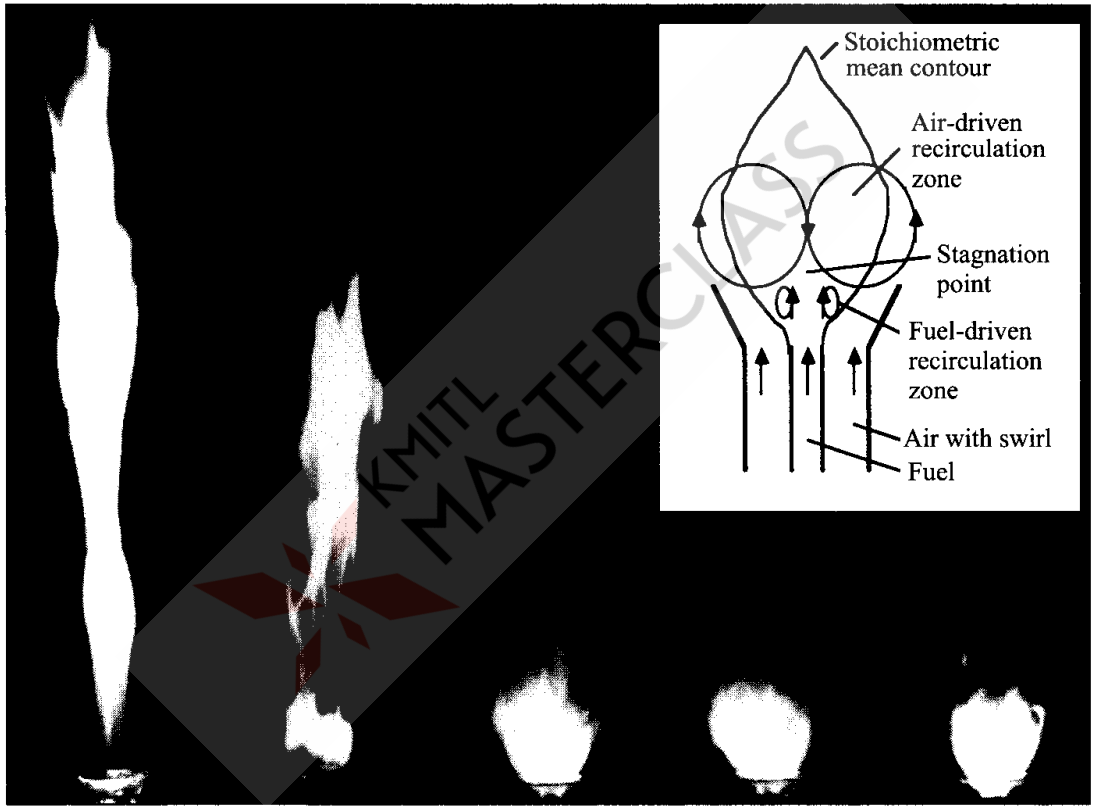
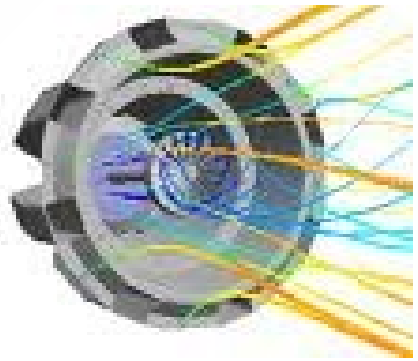
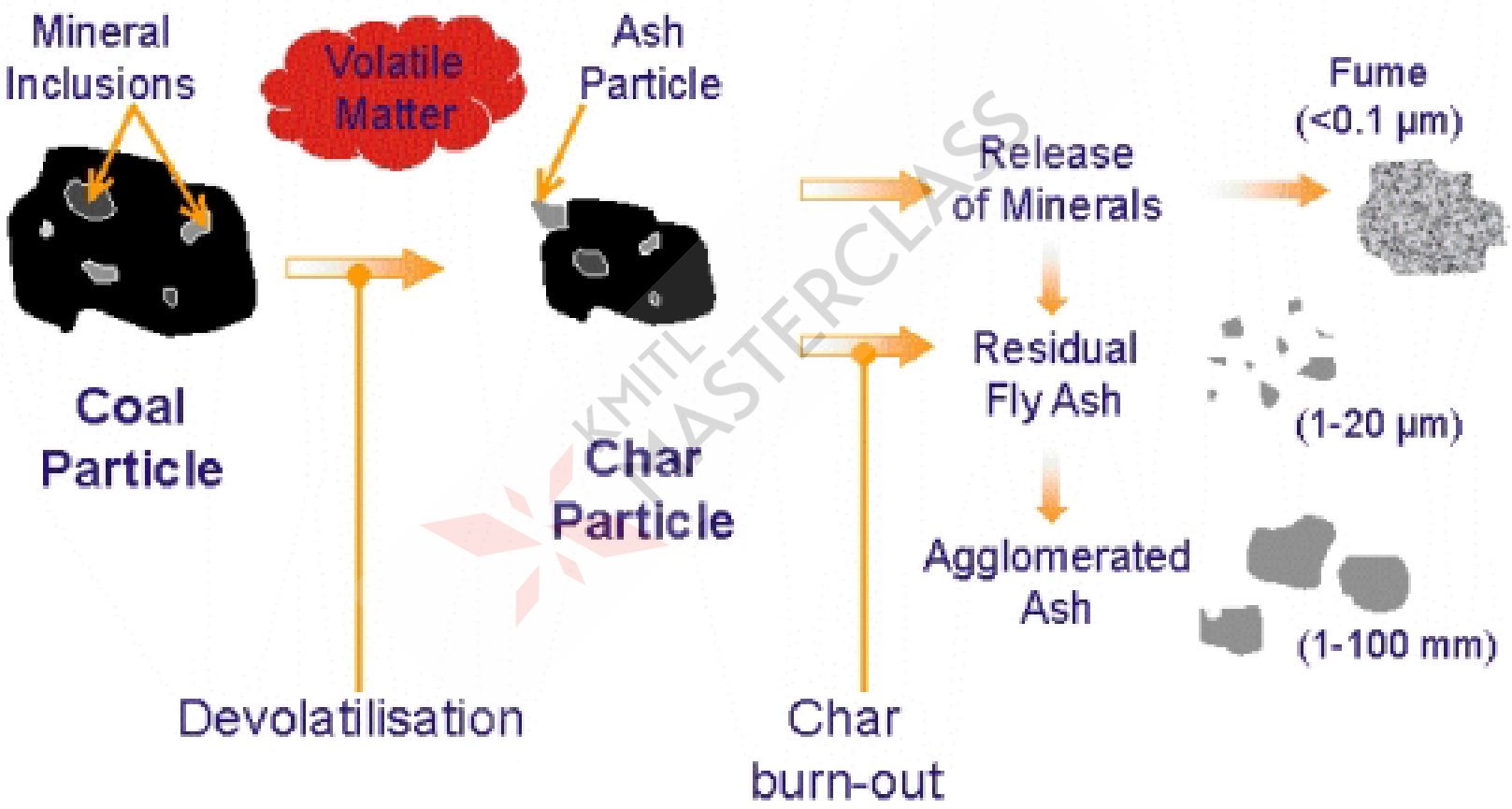


Figure 13.22 Effect of swirl on flame length. Photographic sequence showing no swirl (left) progressing to a swirl number of $S = 1.1$.
SOURCE: Reprinted from Ref. [38] with permission of The Combustion Institute.

Swirler

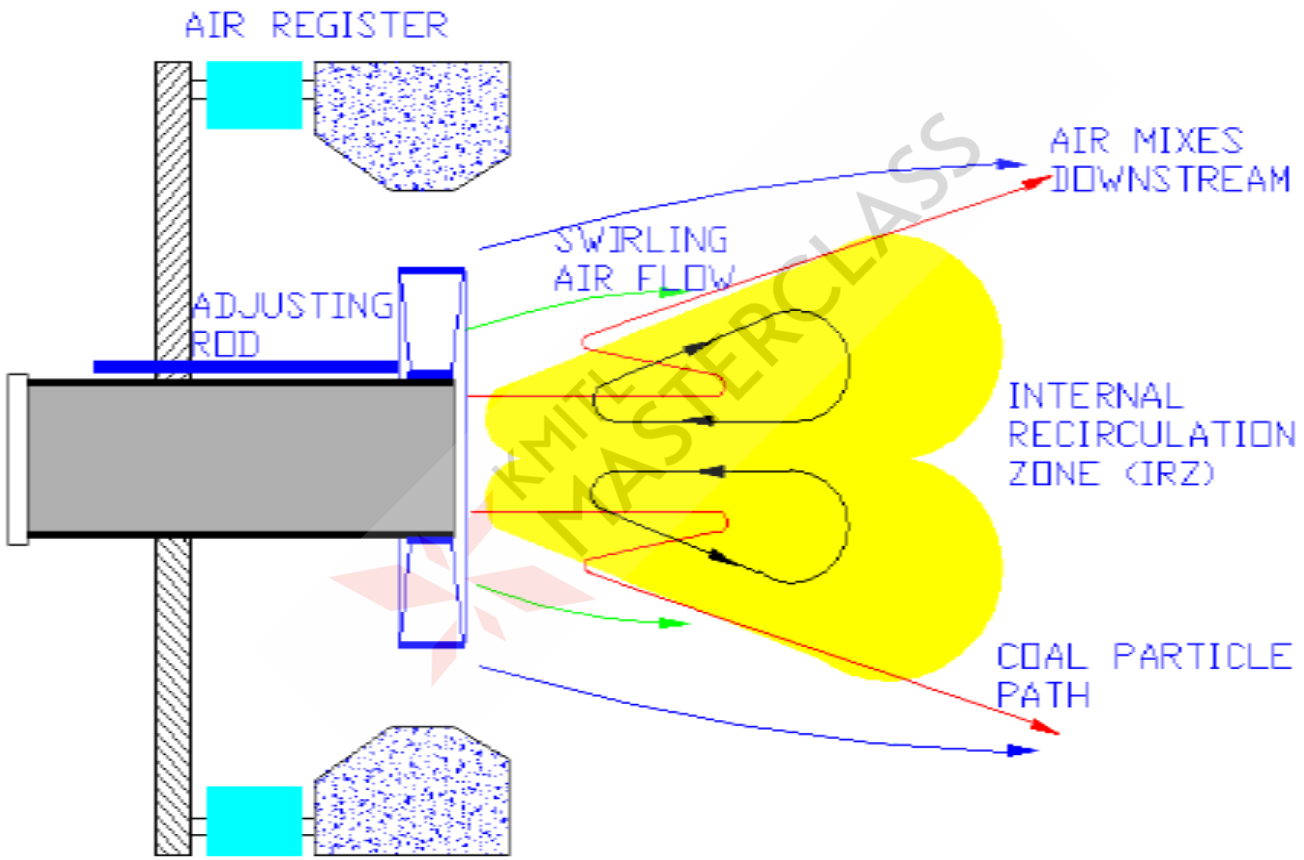


Combustion of solid

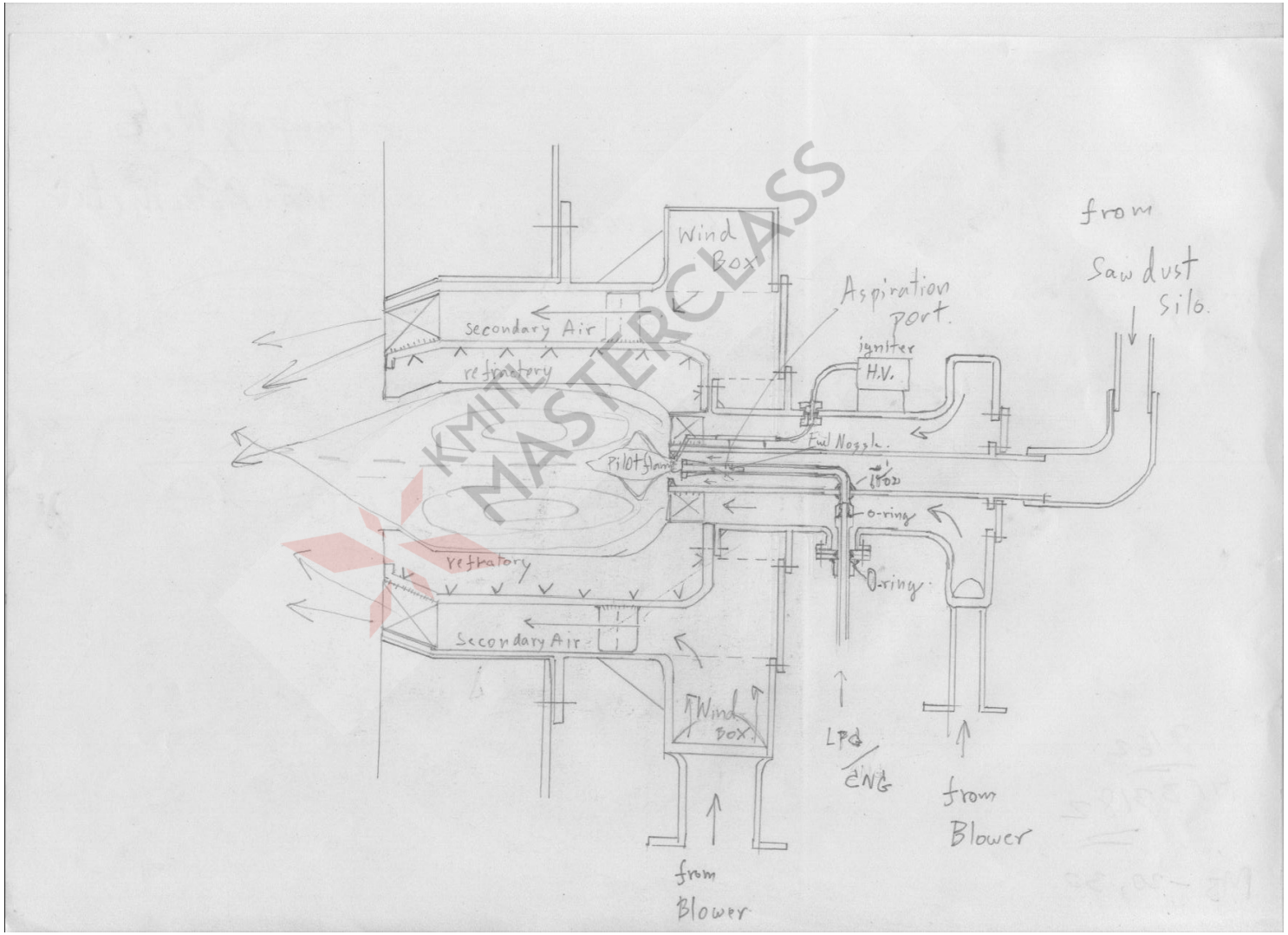


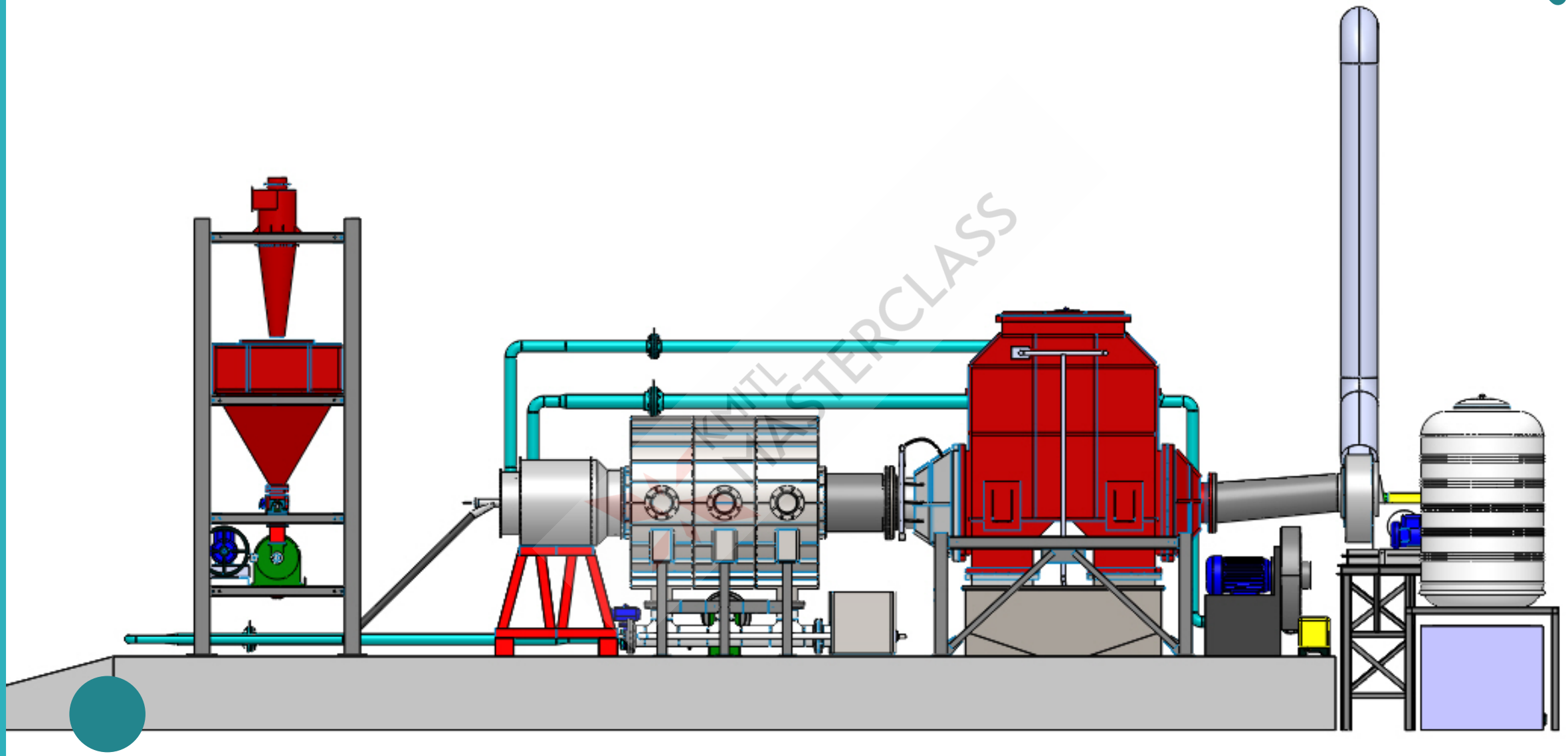
Pulverized coal flame

Interaction between coal particle and air



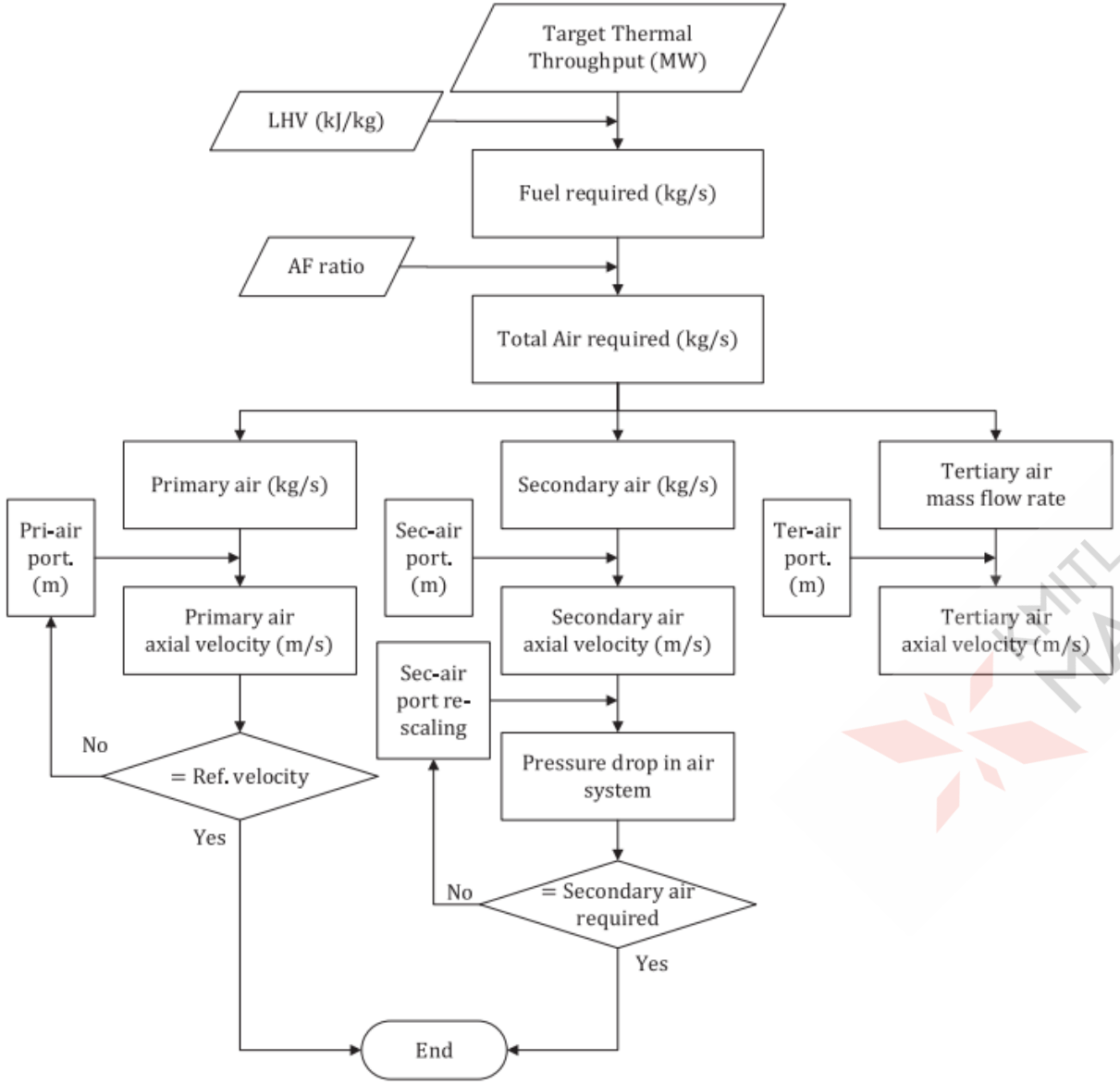
Concept design



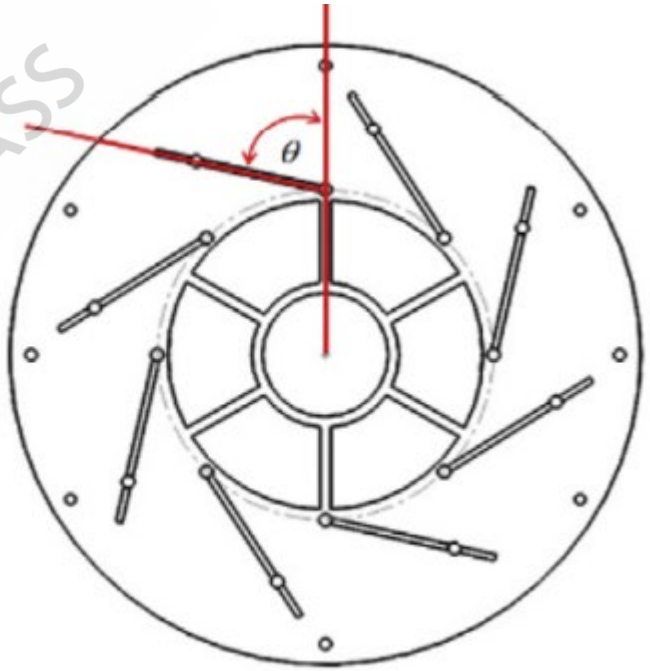


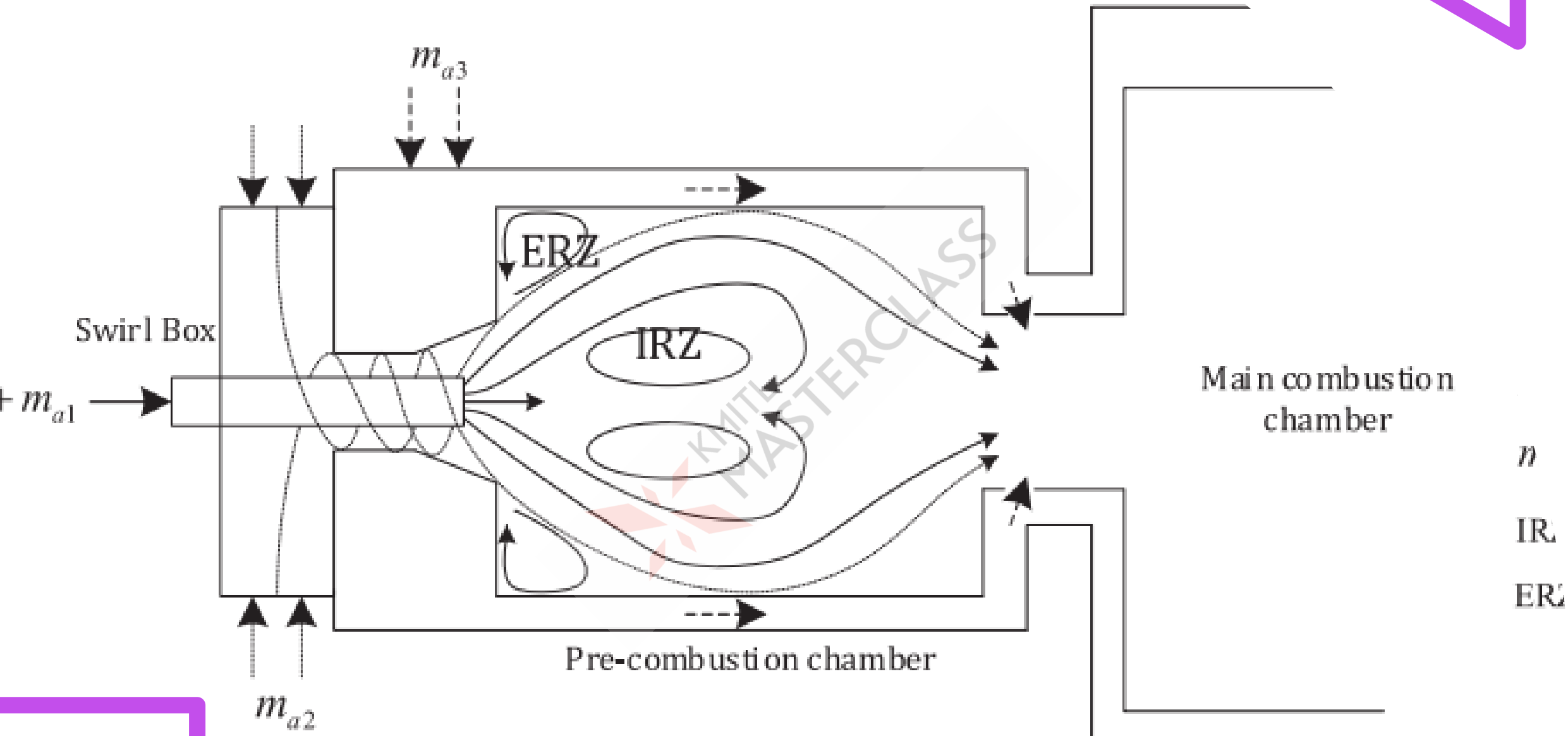
Proximate analysis (as received)	
Moisture %	16.16
Volatiles %	81.41
Ash %	2.43
Fixed carbon %	16.16
Calorific value (MJ/kg, daf)	17.5
Ultimate analysis (wt%, daf)	
C %	45.42
H %	6.31
O %	45.54
N %	0.54

Sizing of equipment

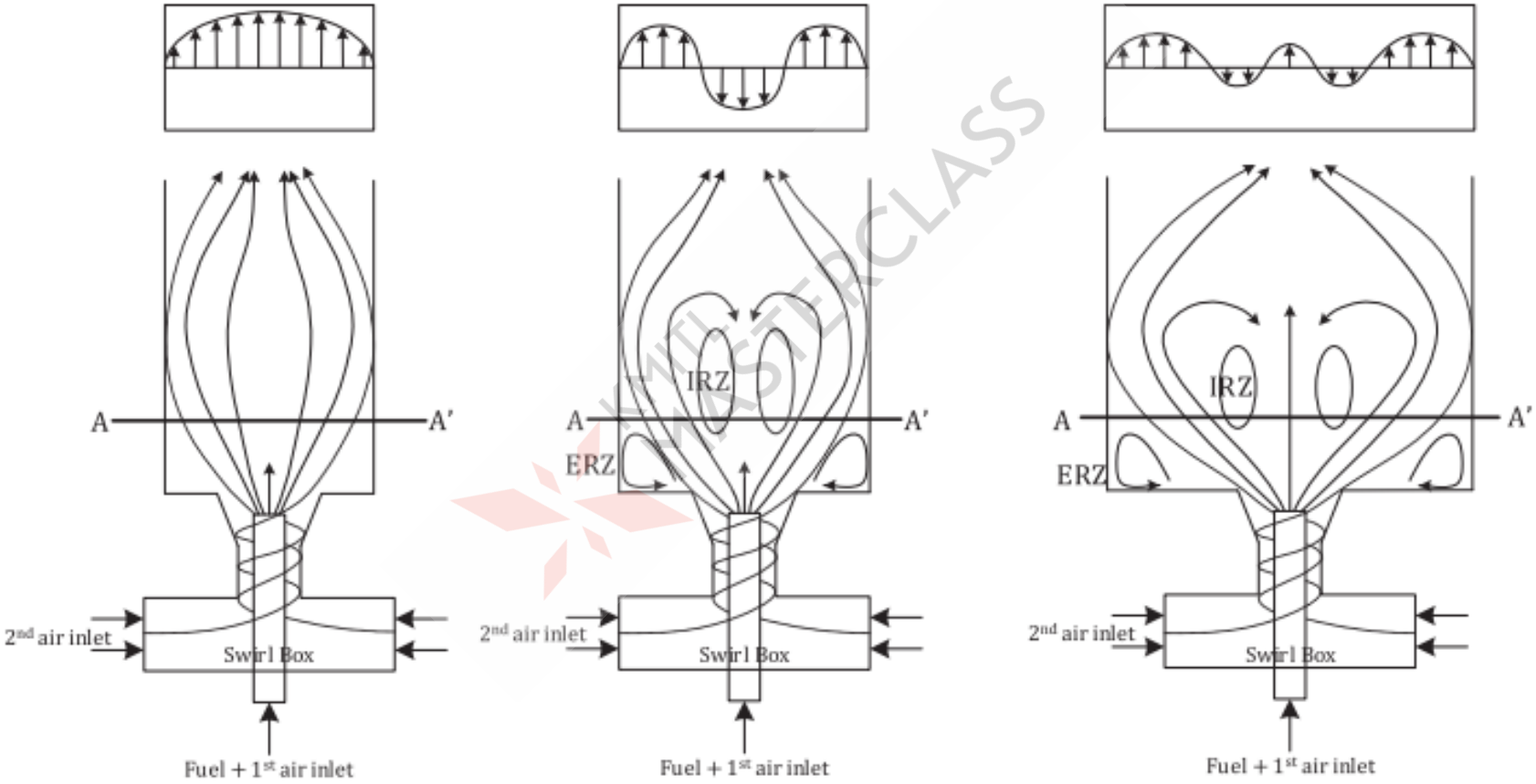


Swirl box

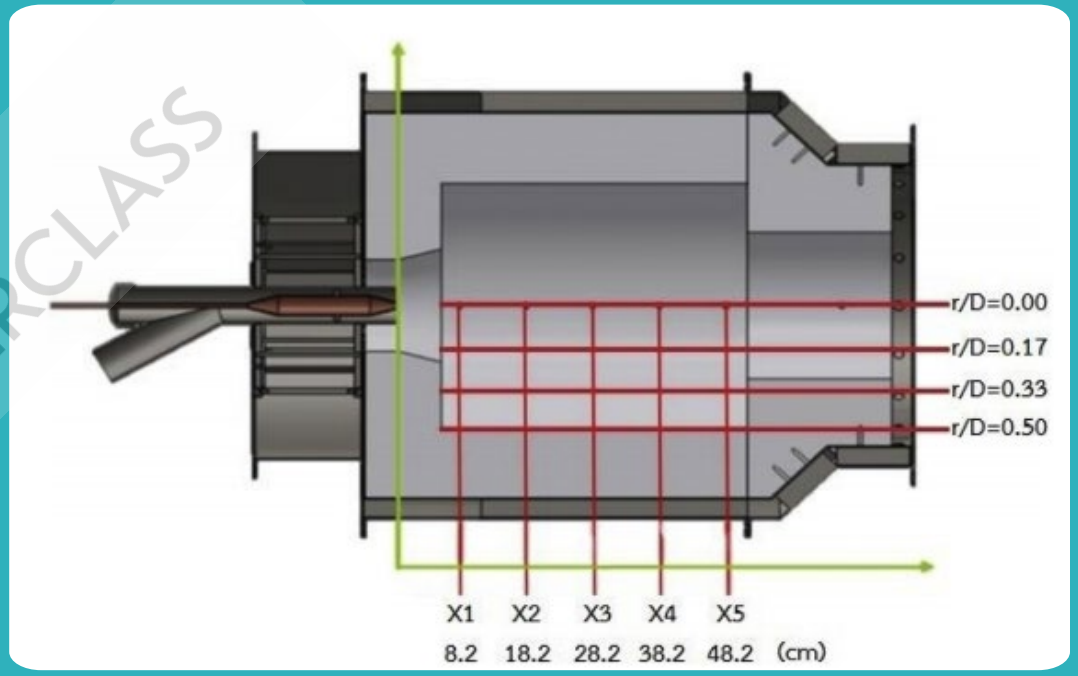


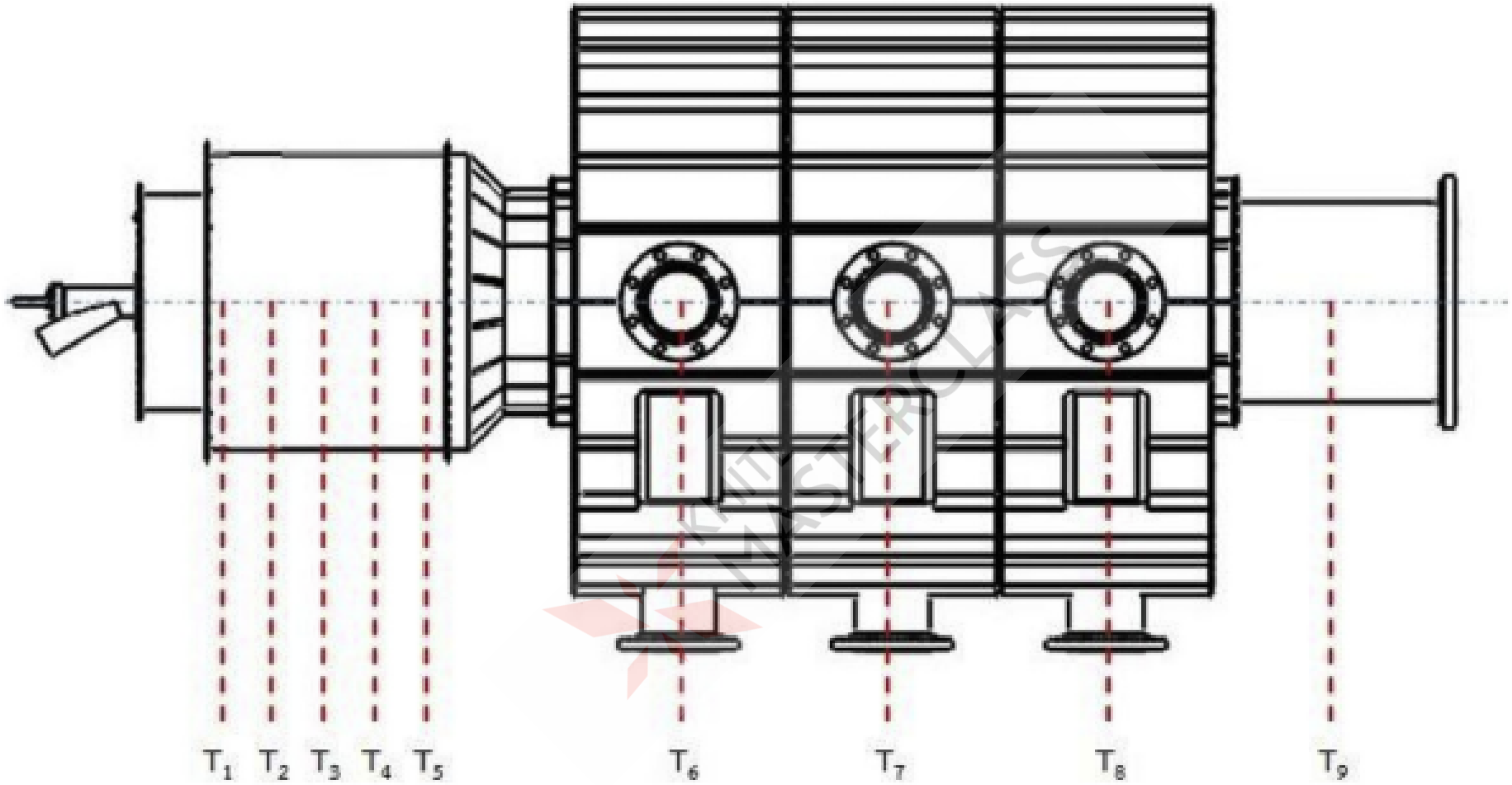

m_{a3}
ERZ
IRZ
Swirl Box
$+ m_{a1}$
Main combustion chamber
Pre-combustion chamber
m_{a2}

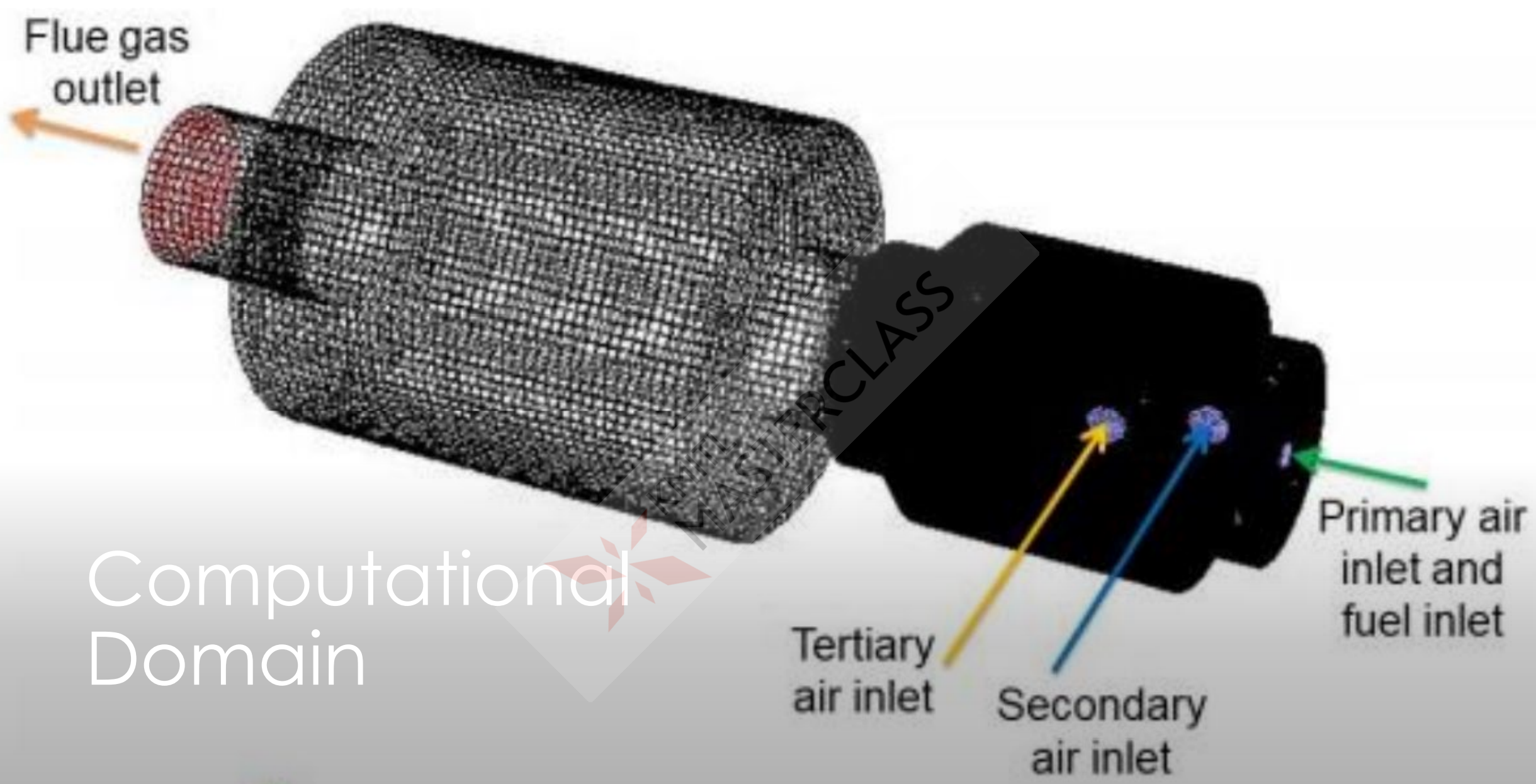
Precombustion chamber



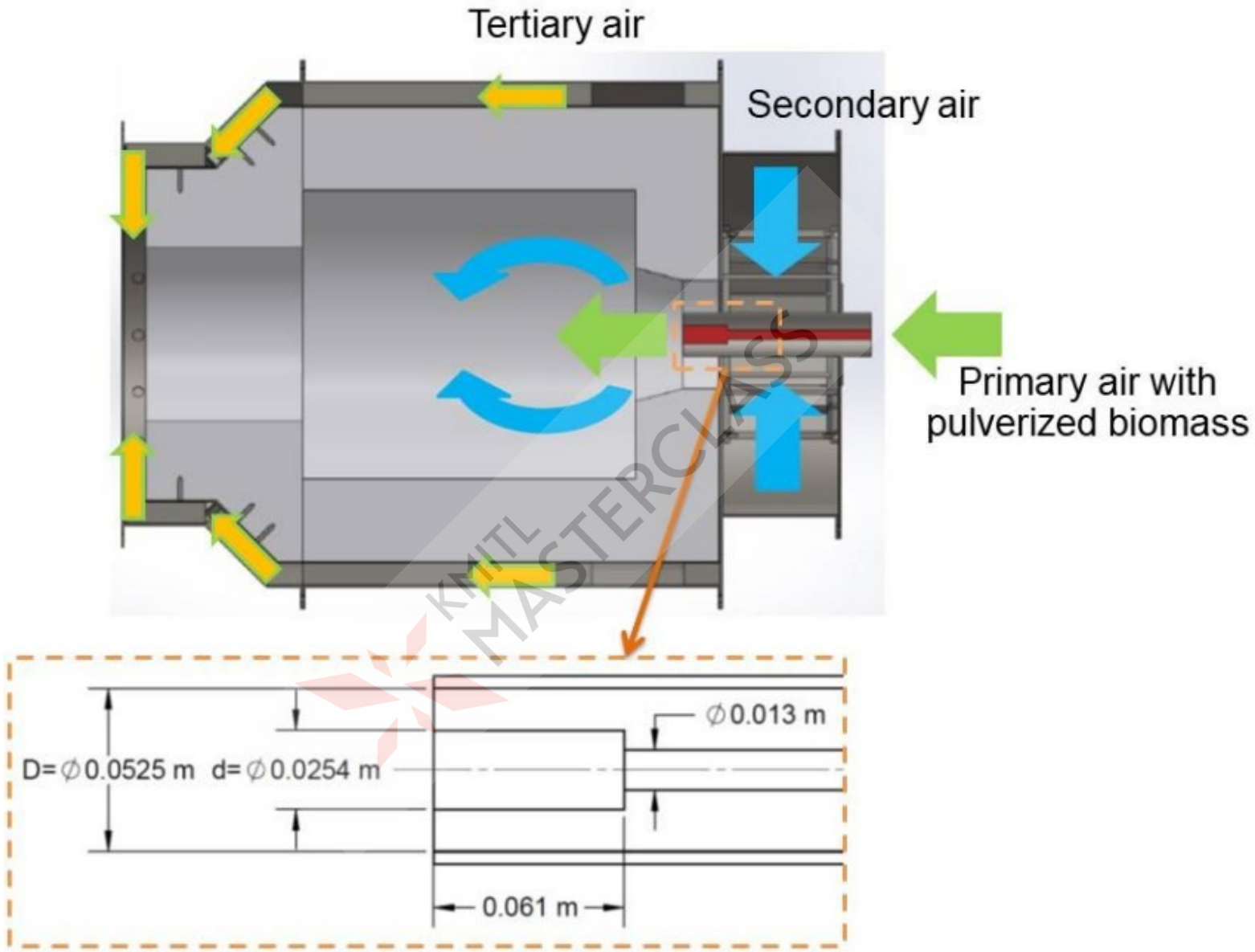
Monitoring location



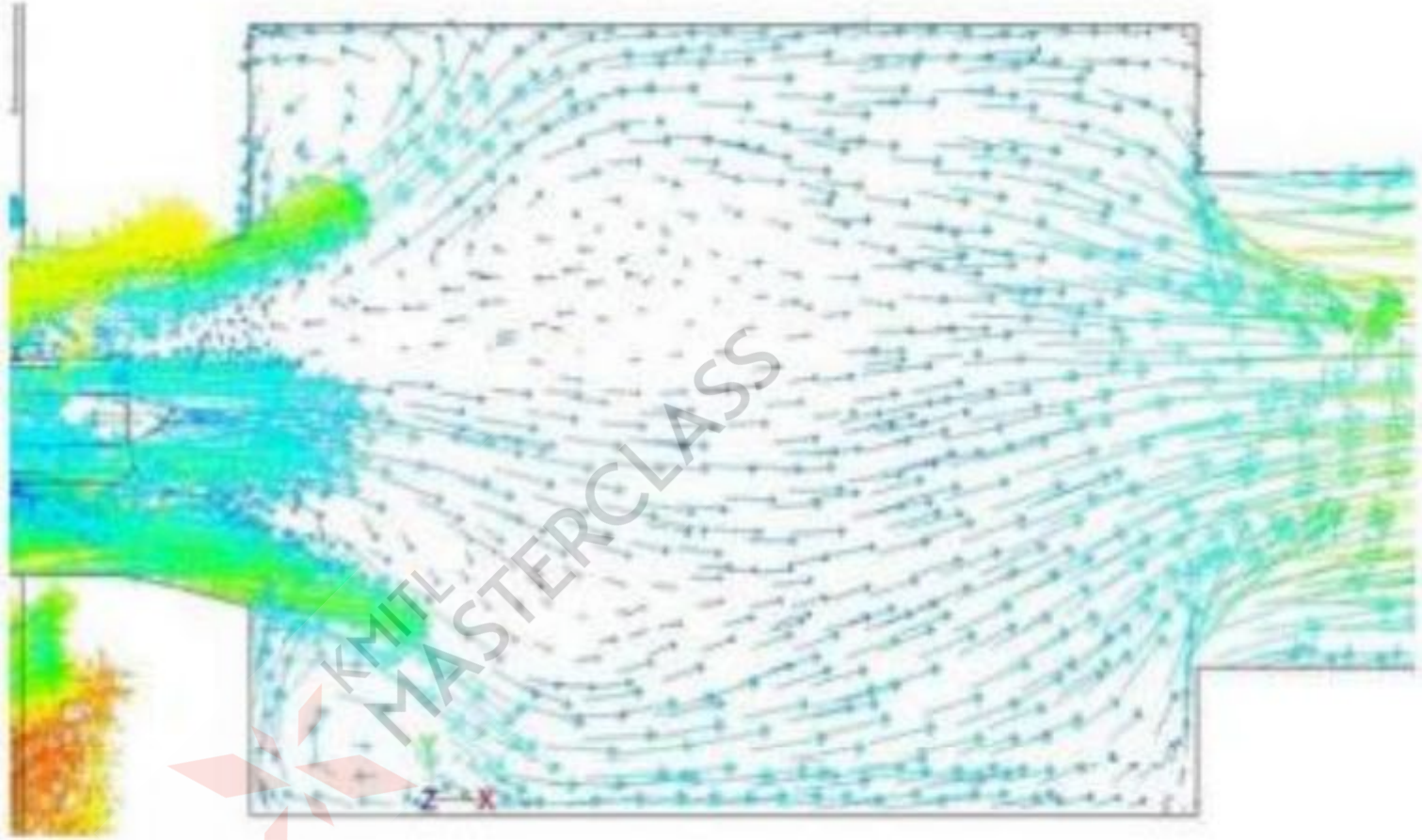

T1
T2
T3
T4
T5
T6
T7
T8
T9

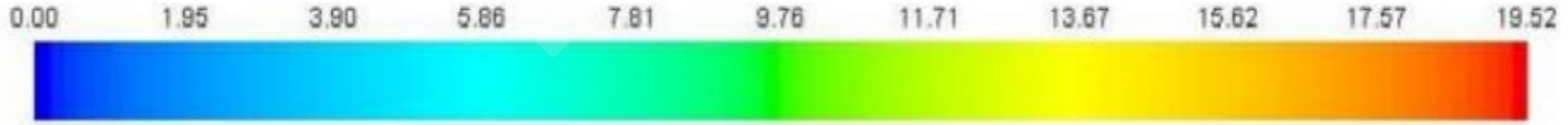


Computational Domain

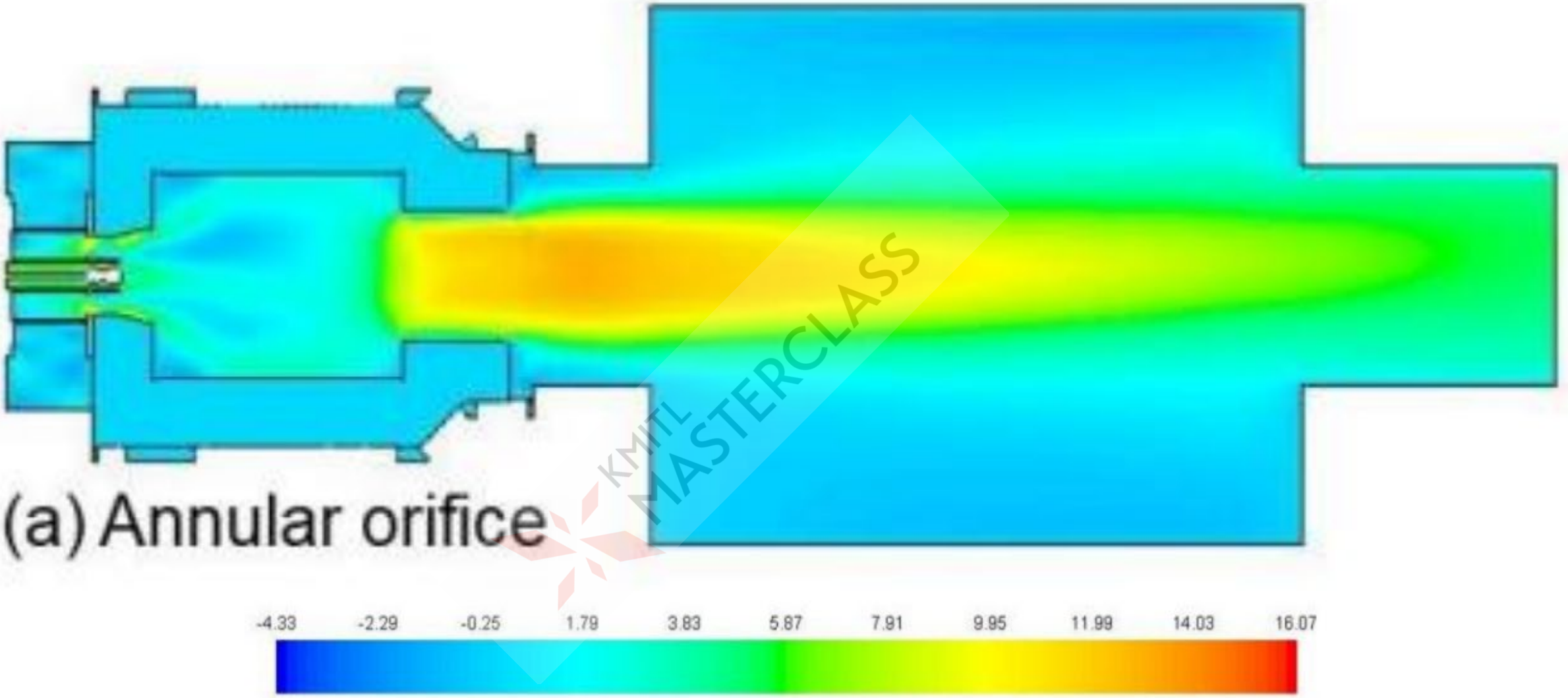

Tertiary air
Secondary air
Primary air with
pulverized biomass
D= ∅0.0525 m
d= ∅0.0254 m
∅0.013 m
0.061 m

(a) Annular orifice



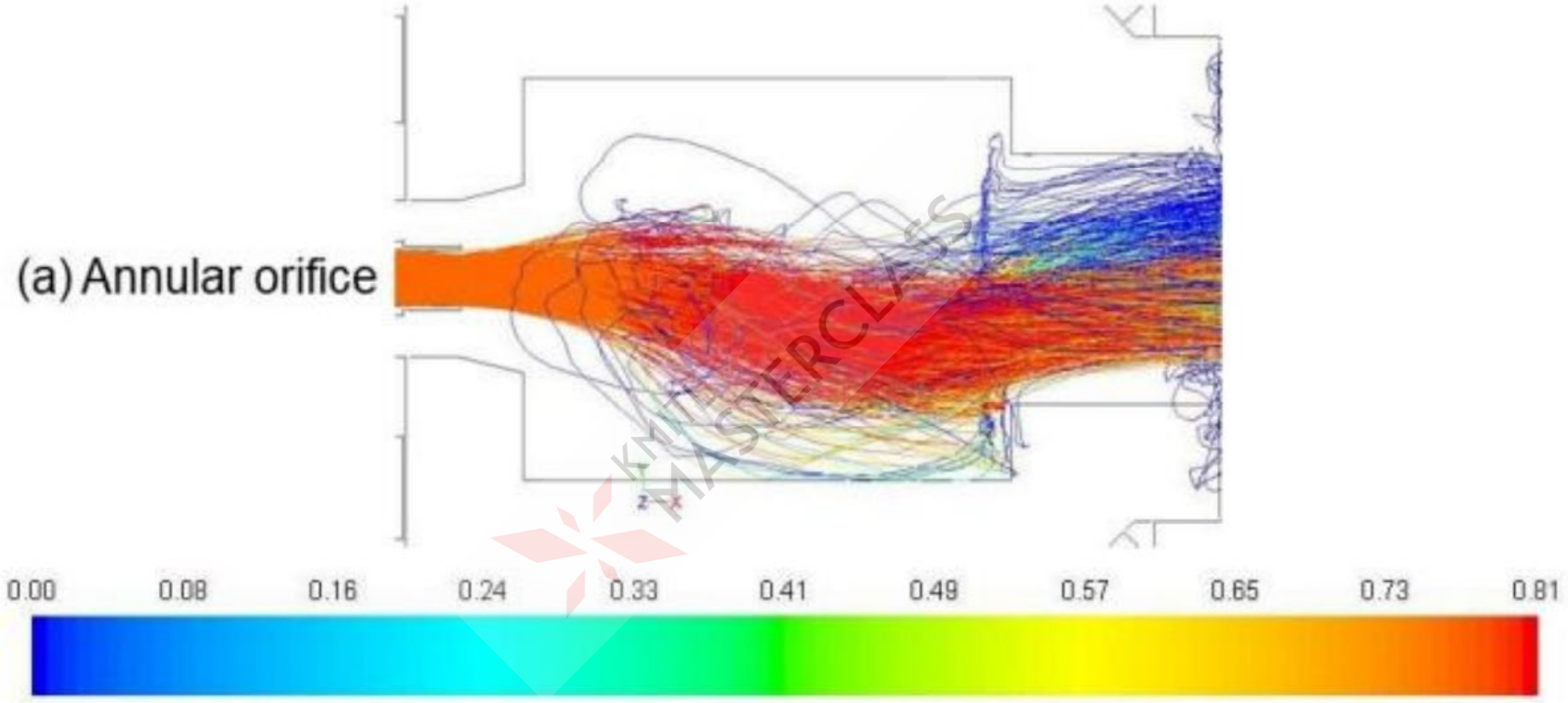


Velocity vectors colored by the velocity magnitude (m/s) i

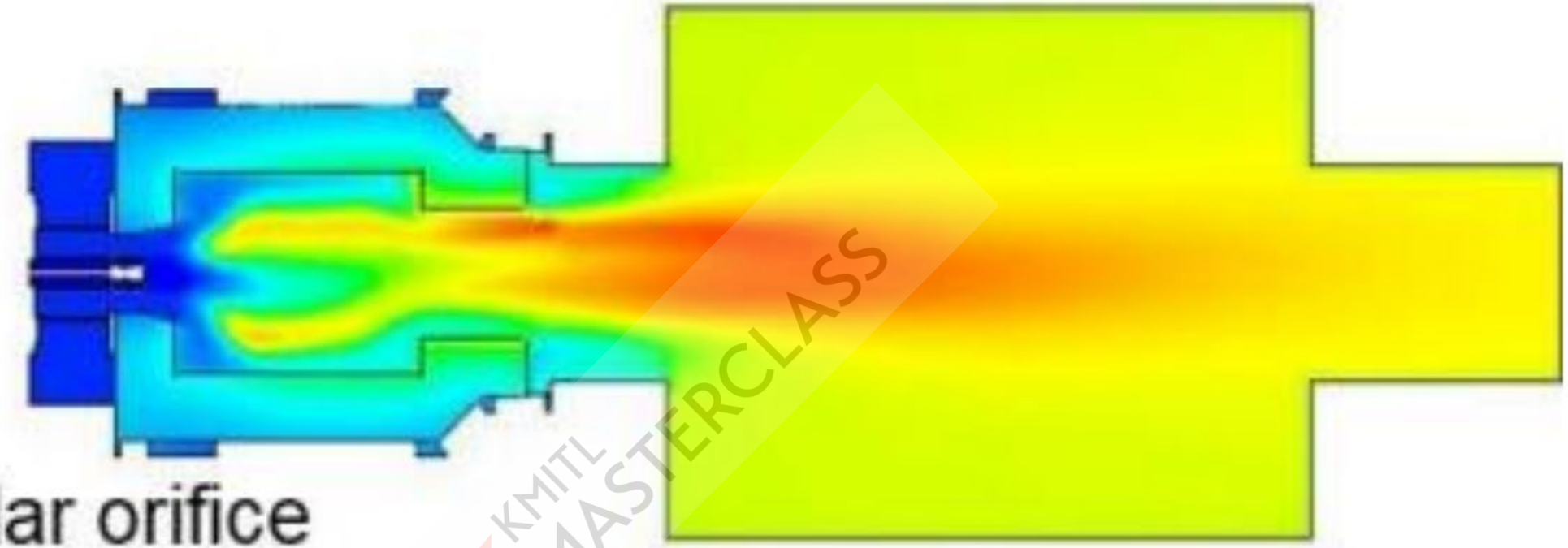


Axial velocity magnitude (m/s) inside the pre-combustion chamber and furnace

(a) Annular orifice

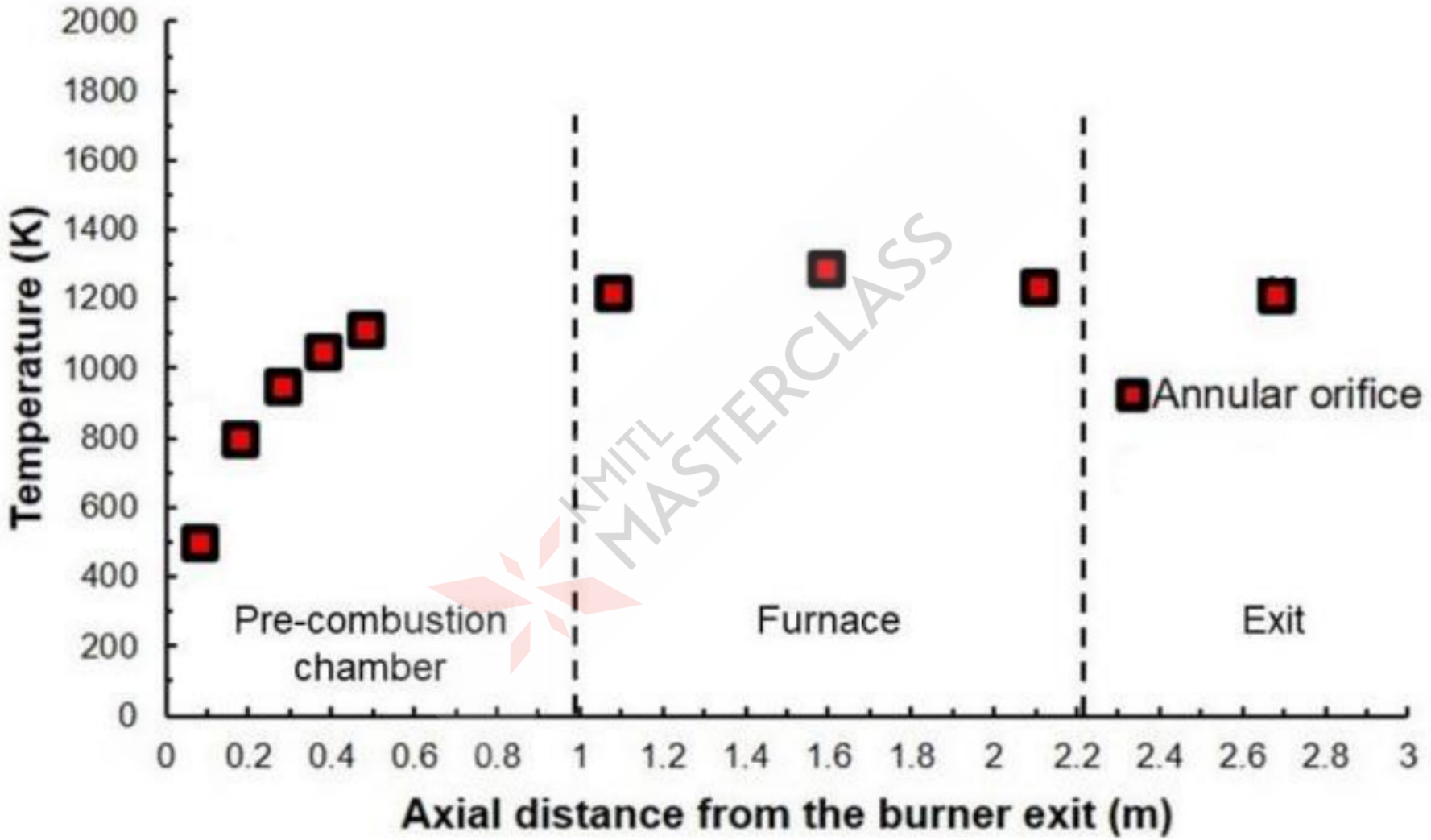


Particle trajectory colored by a volatiles mass fraction inside the pre-combustion chamber

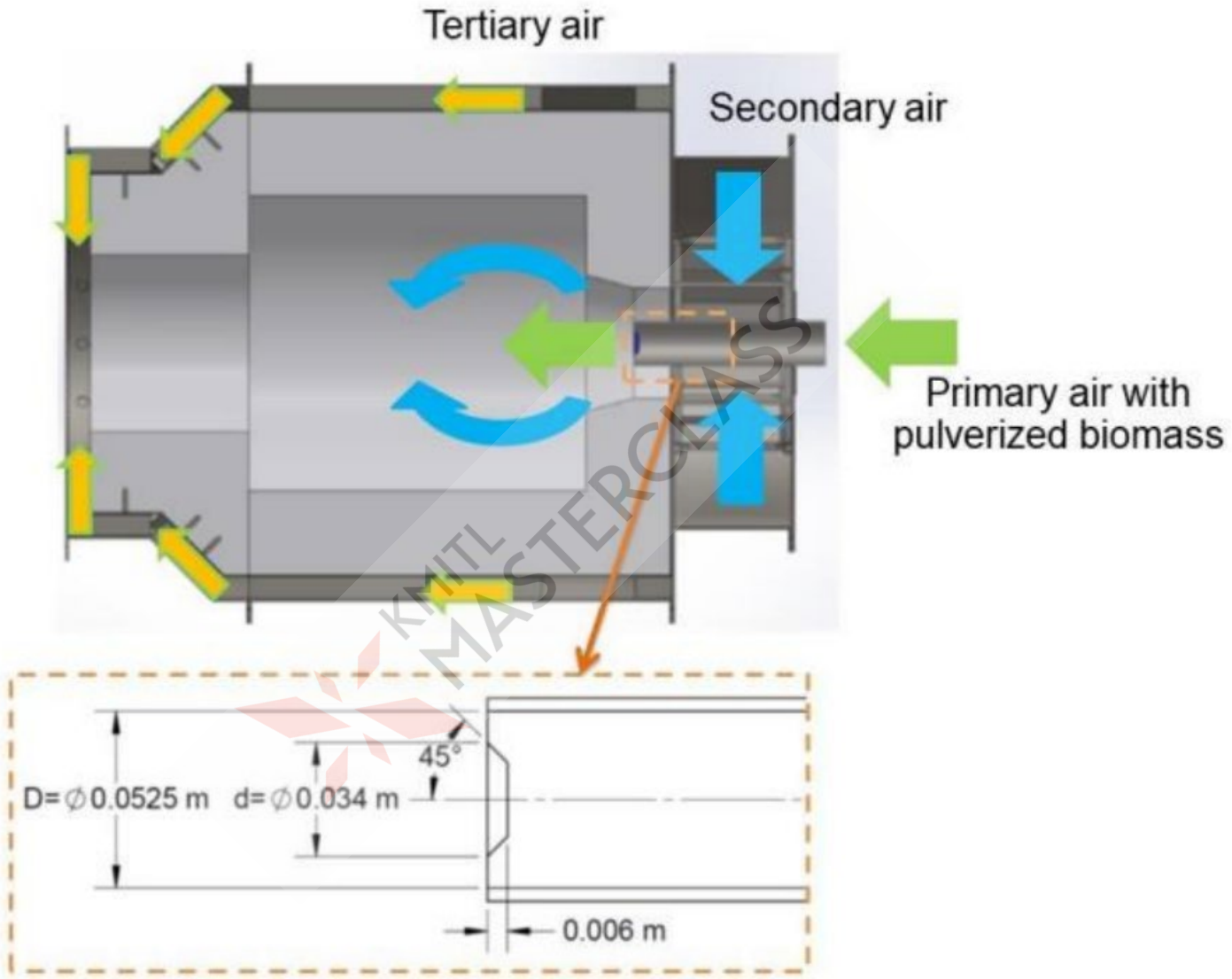


(a) Annular orifice

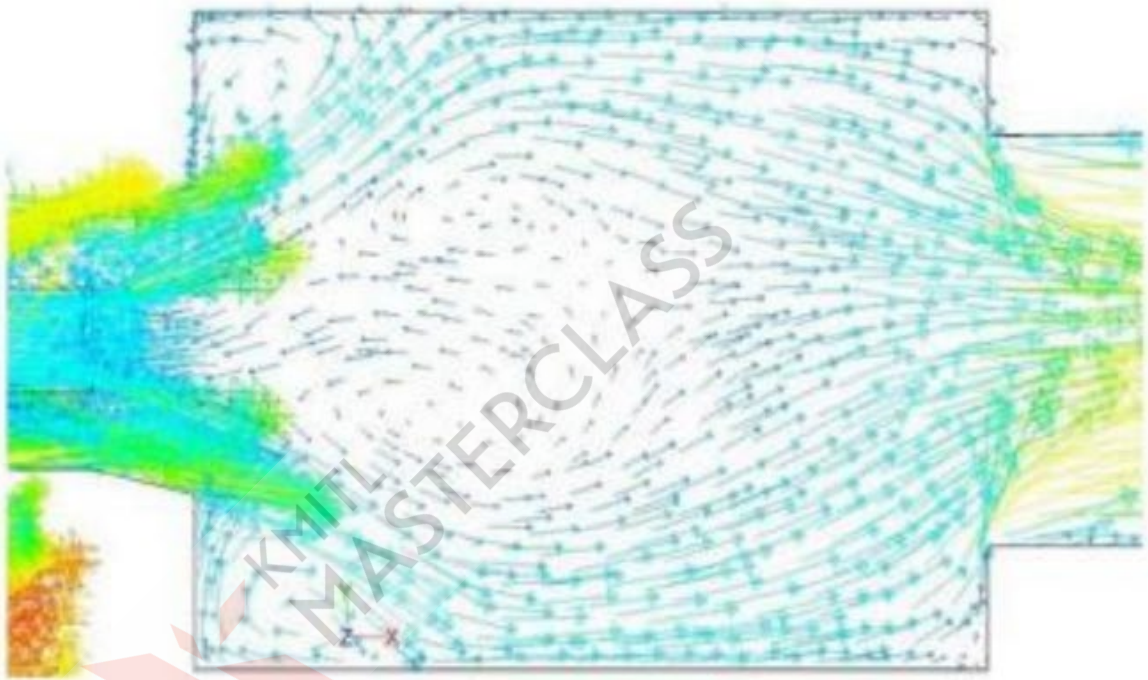
Temperature (K) distribution inside the pre-combustion chamber and furnace

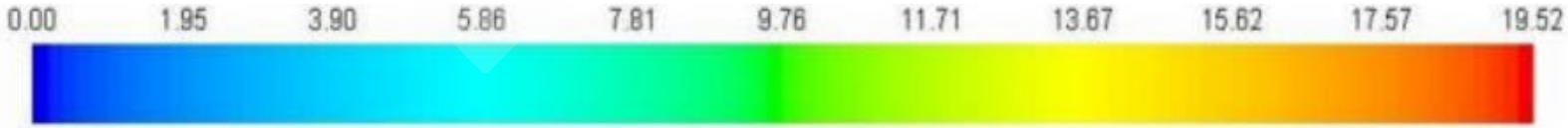

Temperature (K)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Axial distance from the burner exit (m)
Pre-combustion chamber
Furnace
Exit
Annular orifice

Flame inside the pre-combustion chamber of the annular orifice (

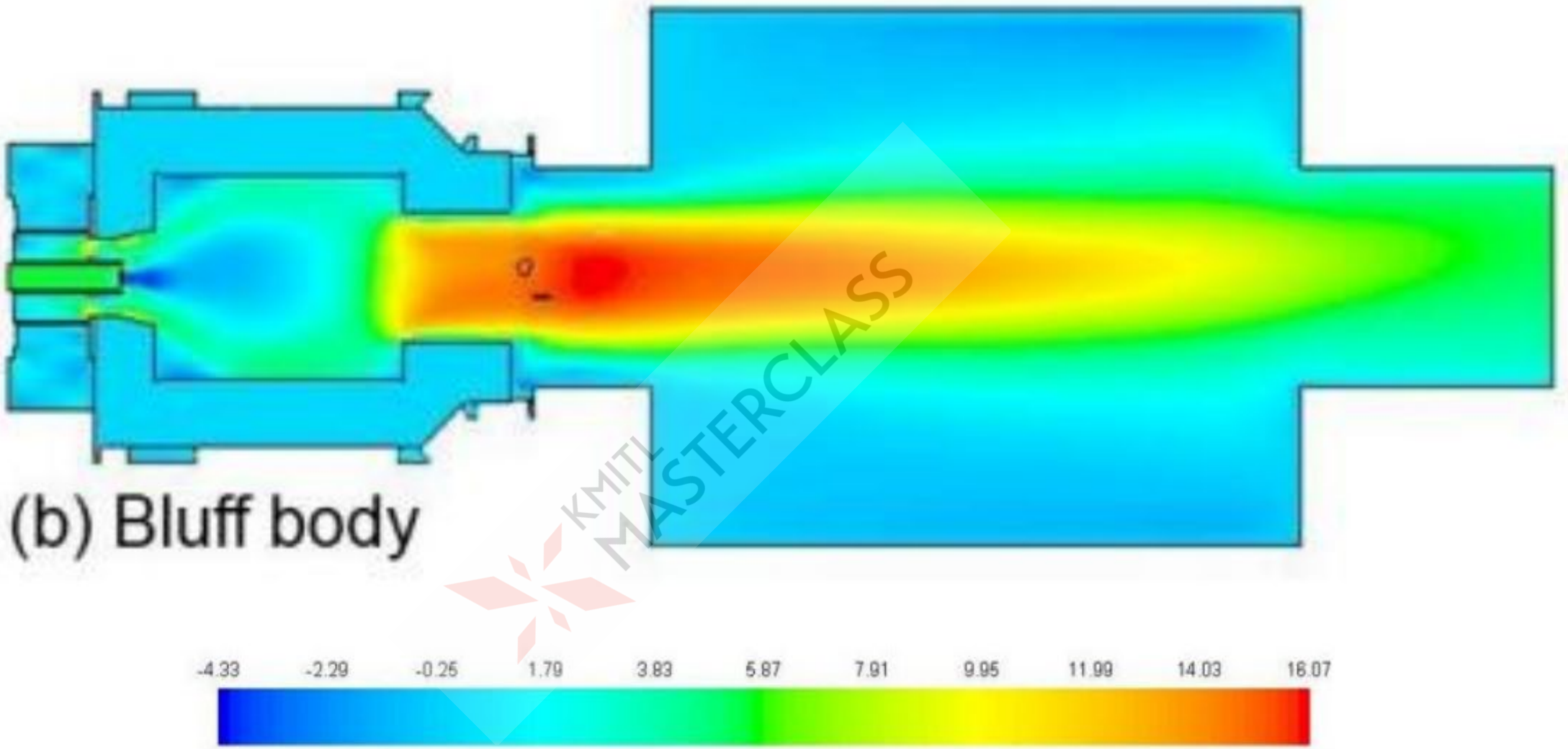

Tertiary air
Secondary air
Primary air with
pulverized biomass
45°
D=∅0.0525 m
d=∅0.034 m
0.006 m

(b) Bluff body



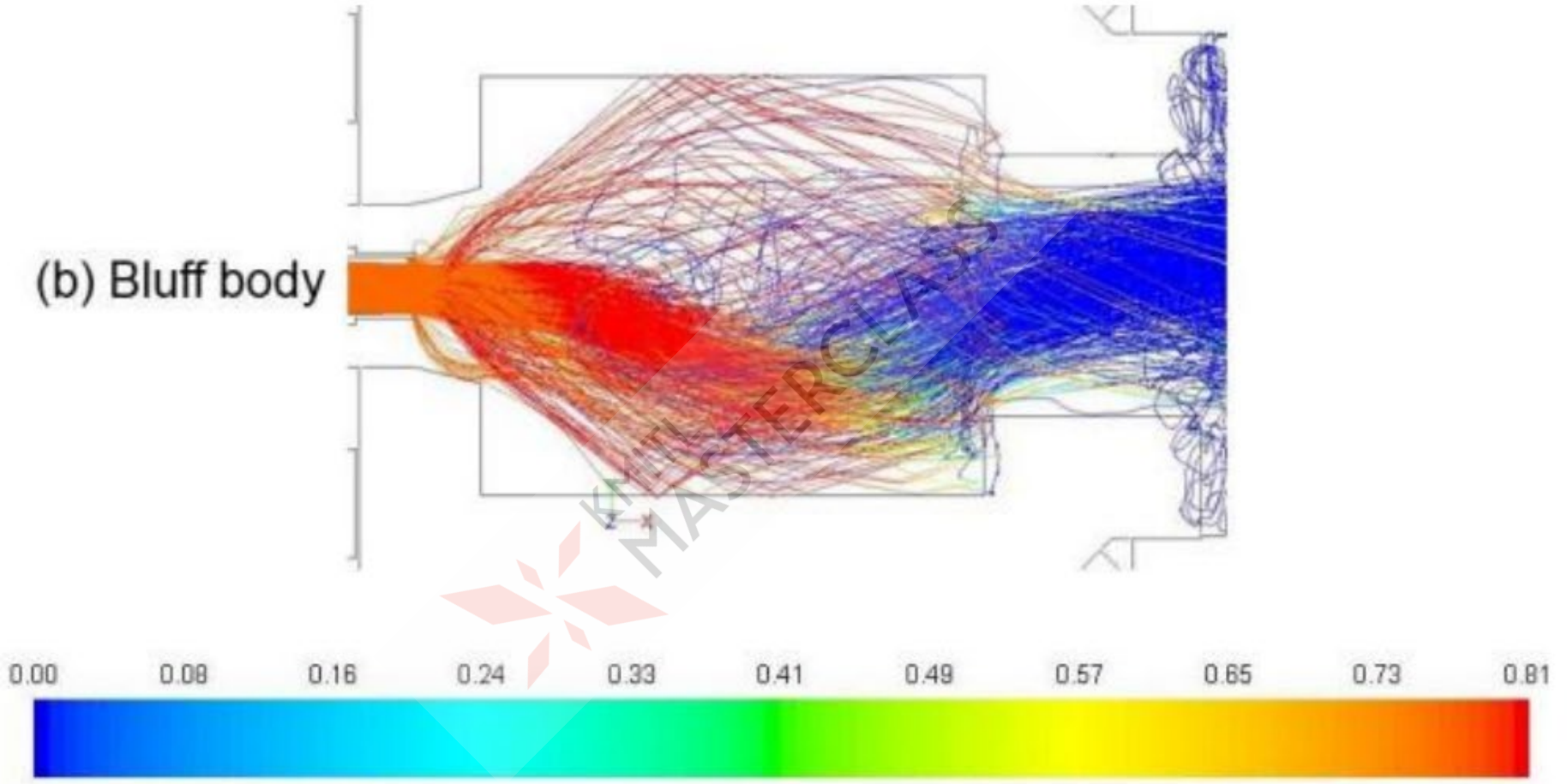


Velocity vectors colored by the velocity magnitude (m/s) i

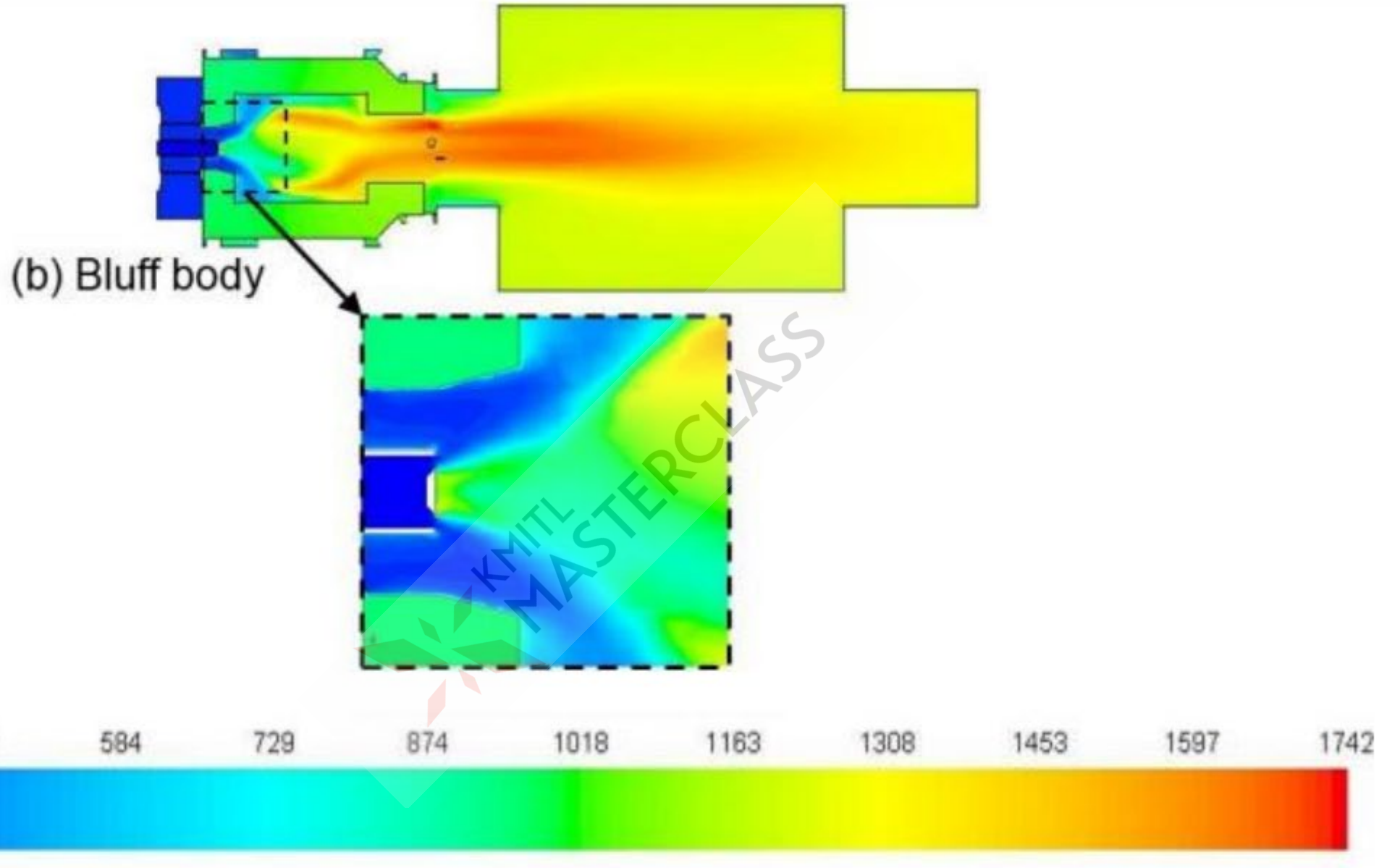


Axial velocity magnitude (m/s) inside the pre-combustion chamber and furnace

(b) Bluff body



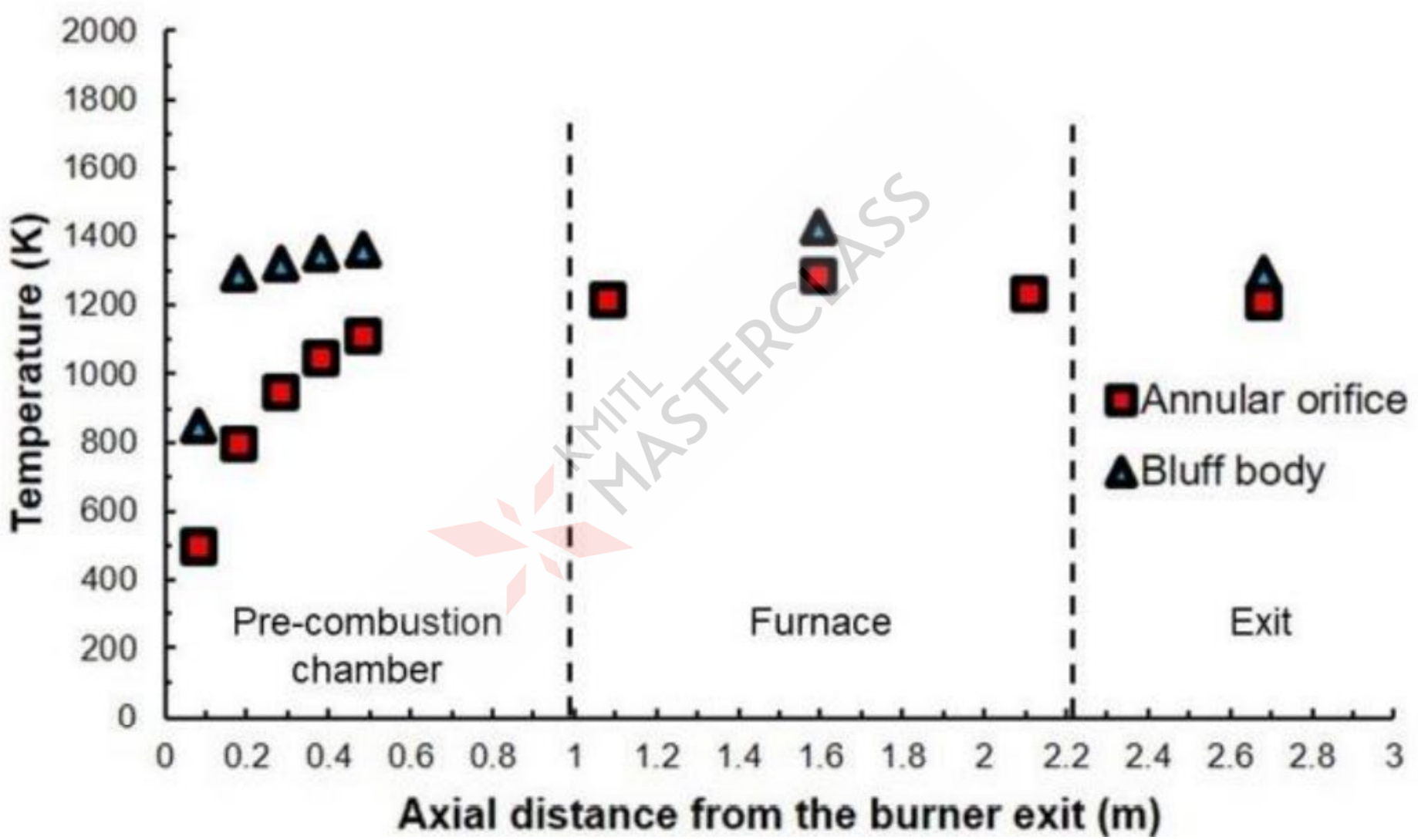
Particle trajectory colored by a volatiles mass fraction inside the pre-combustion chamber



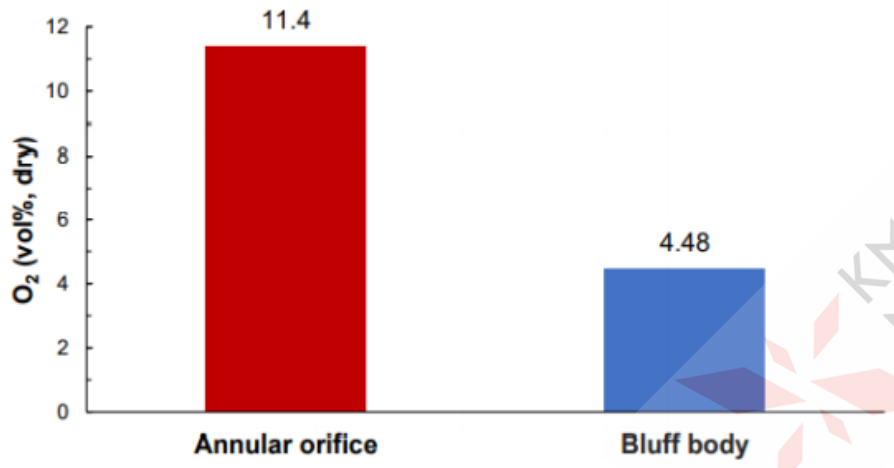
Temperature (K) distribution inside the pre-combustion chamber and furnace

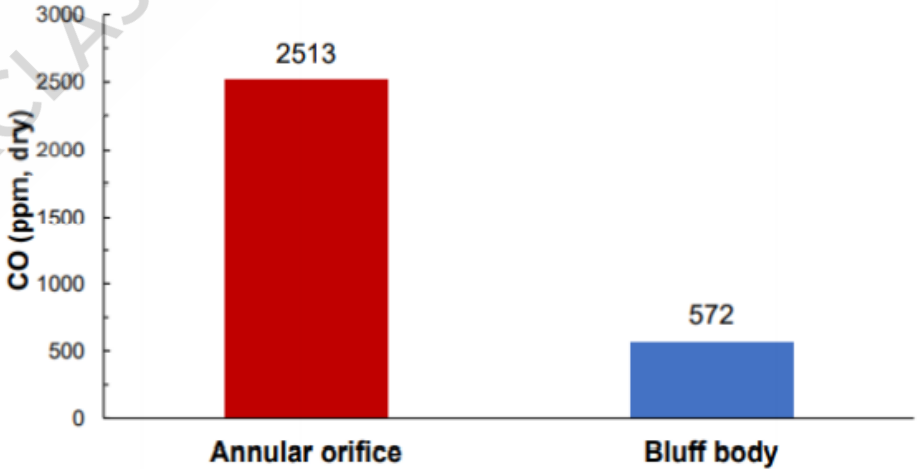
(b)

Flame inside the pre-combustion chamber of the annular orifice (

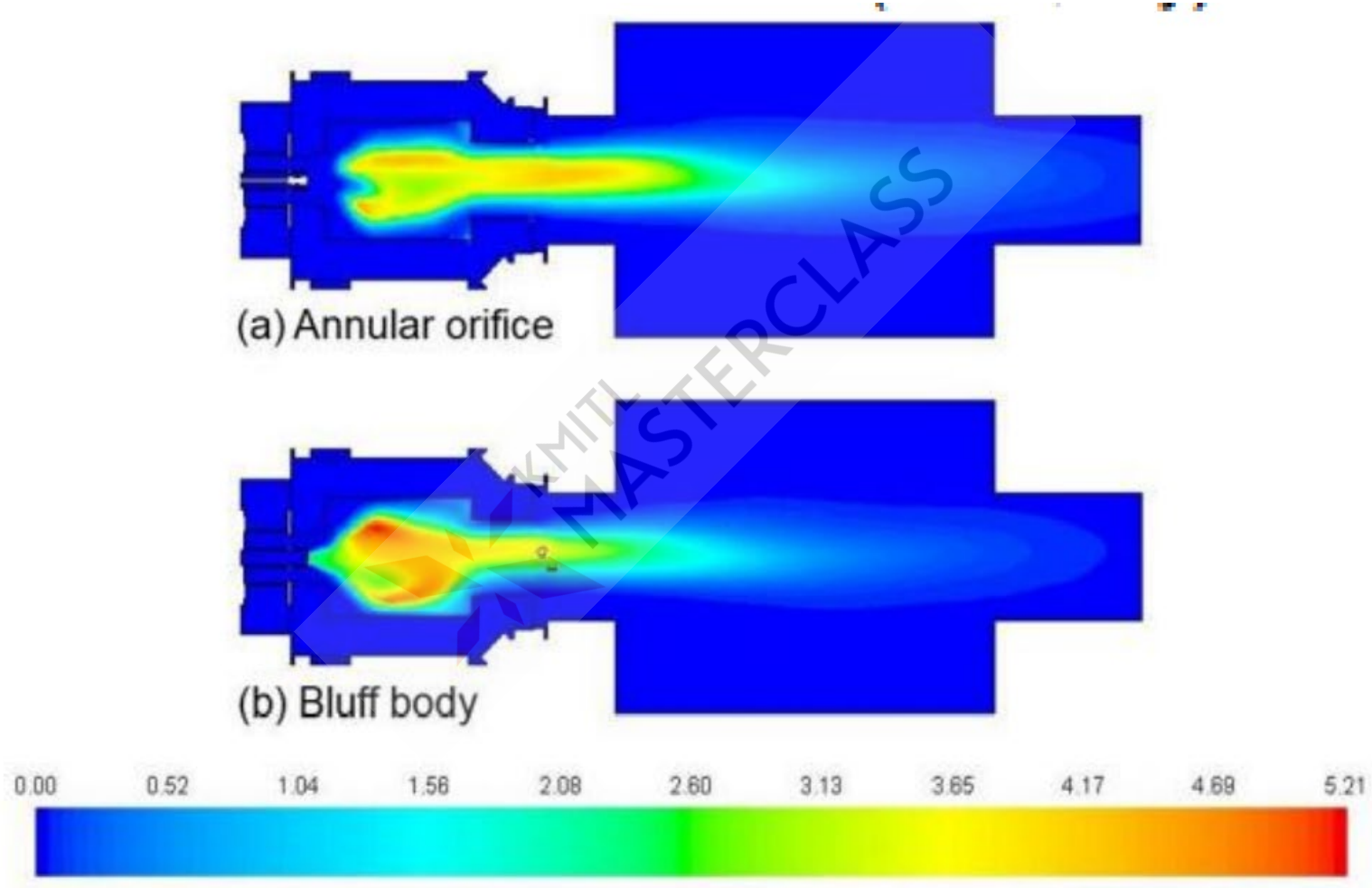

Temperature (K)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Axial distance from the burner exit (m)
Pre-combustion chamber
Furnace
Exit
Annular orifice
Bluff body

ความสมบูรณ์ของการเผาไหม้

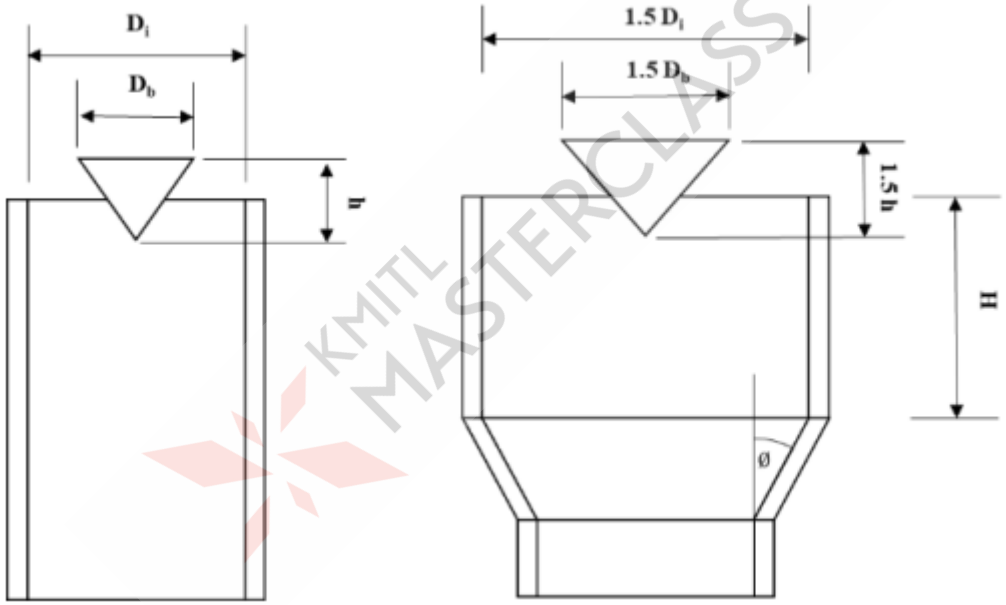




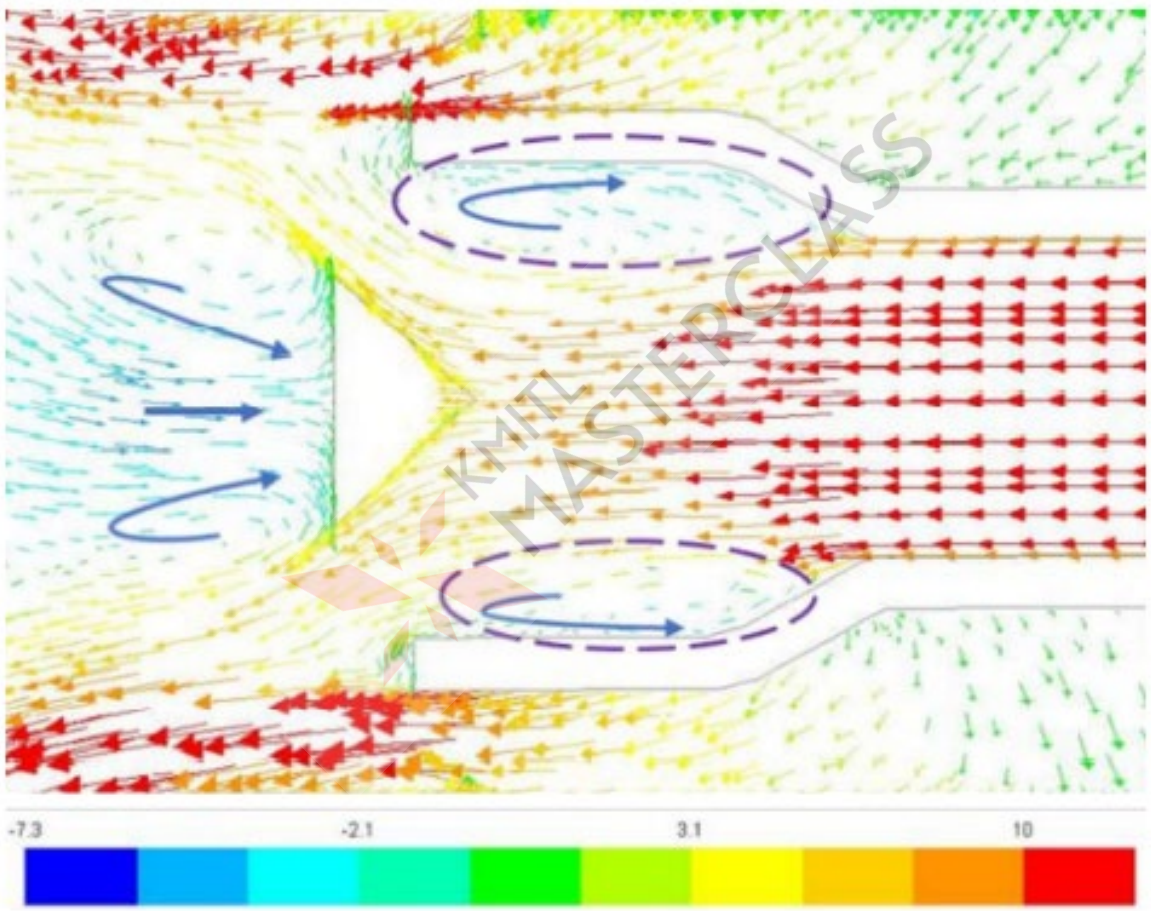
CO concentration (%vol, dry)



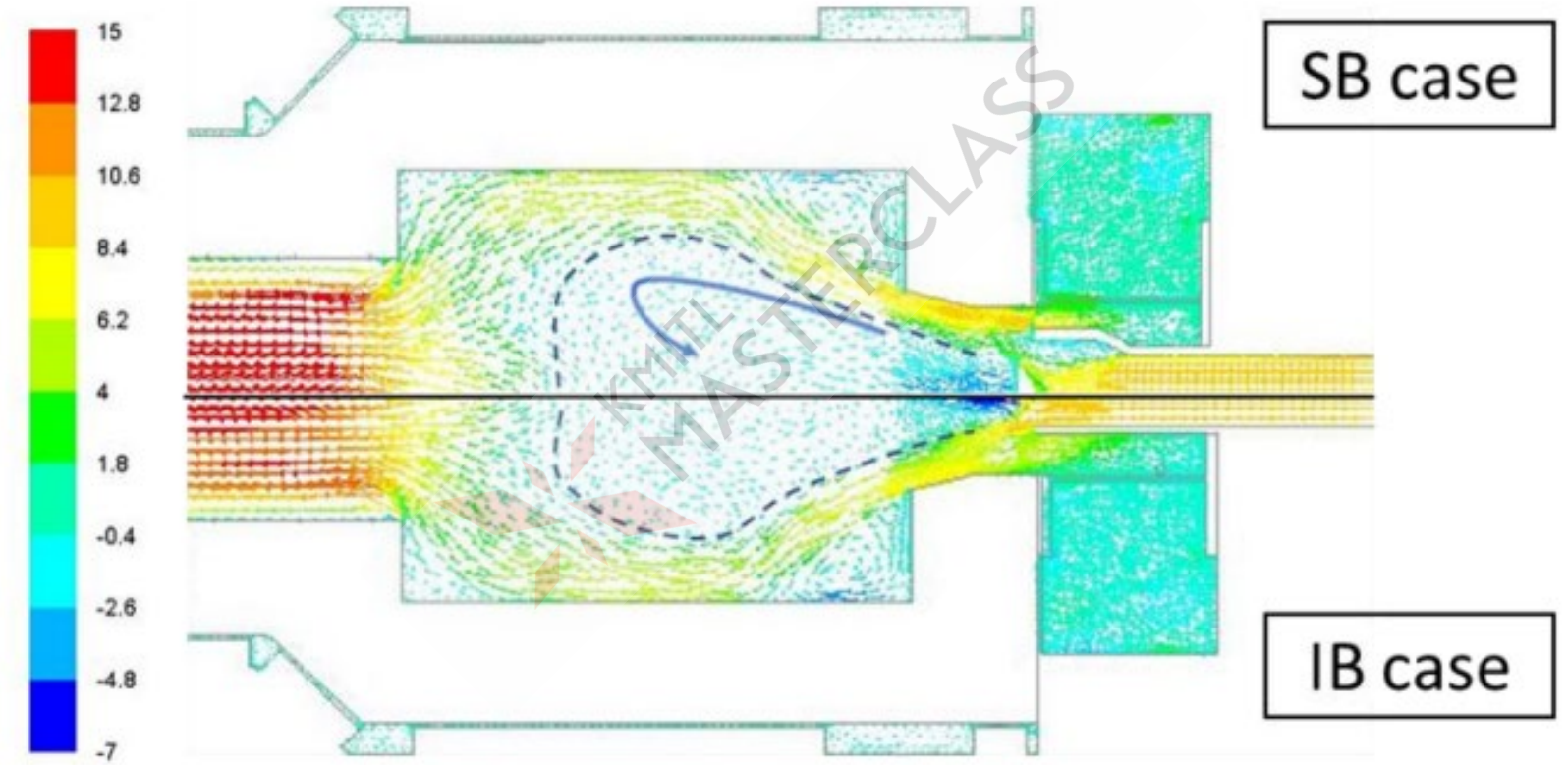
Burner tip modification:

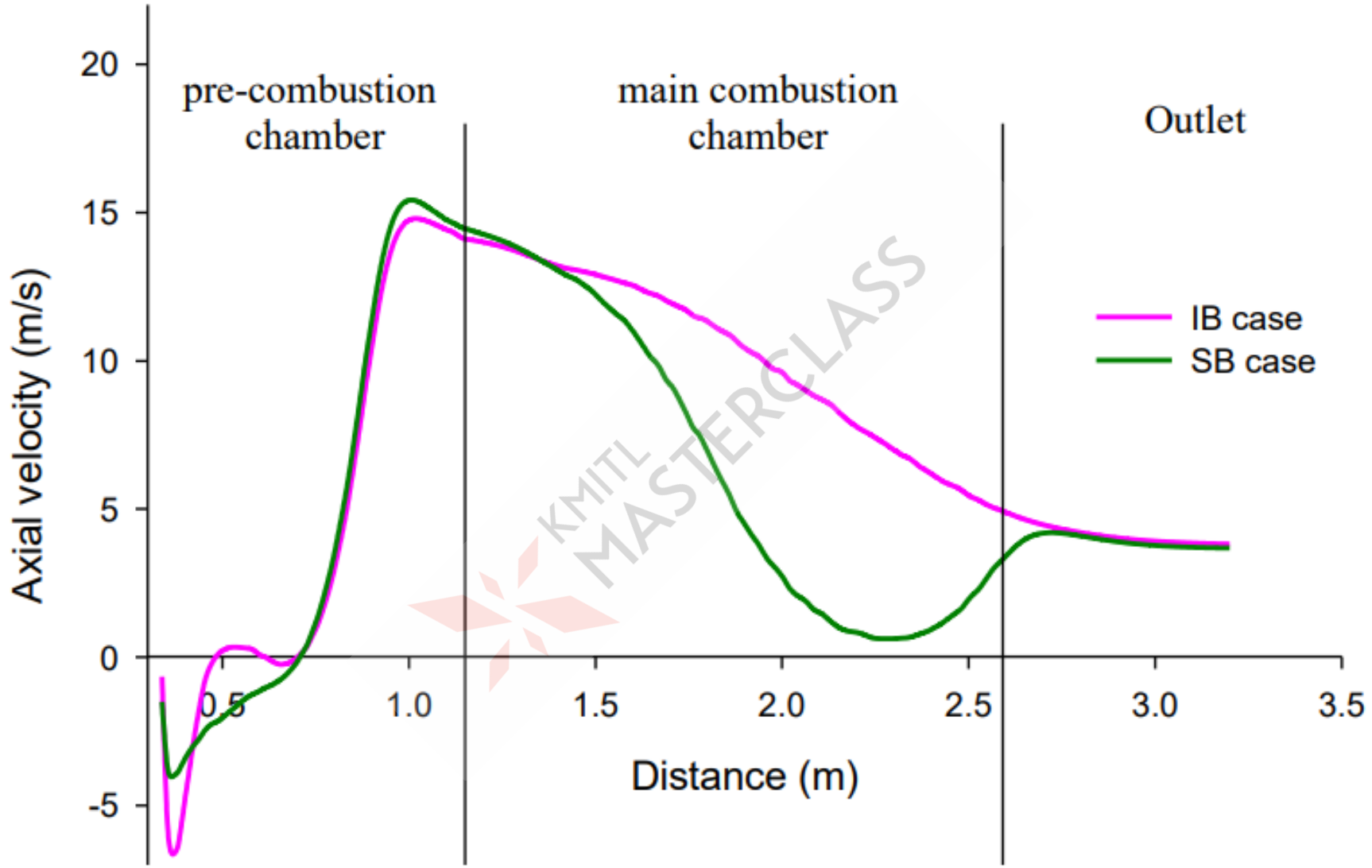


Burner tip aerodynamics

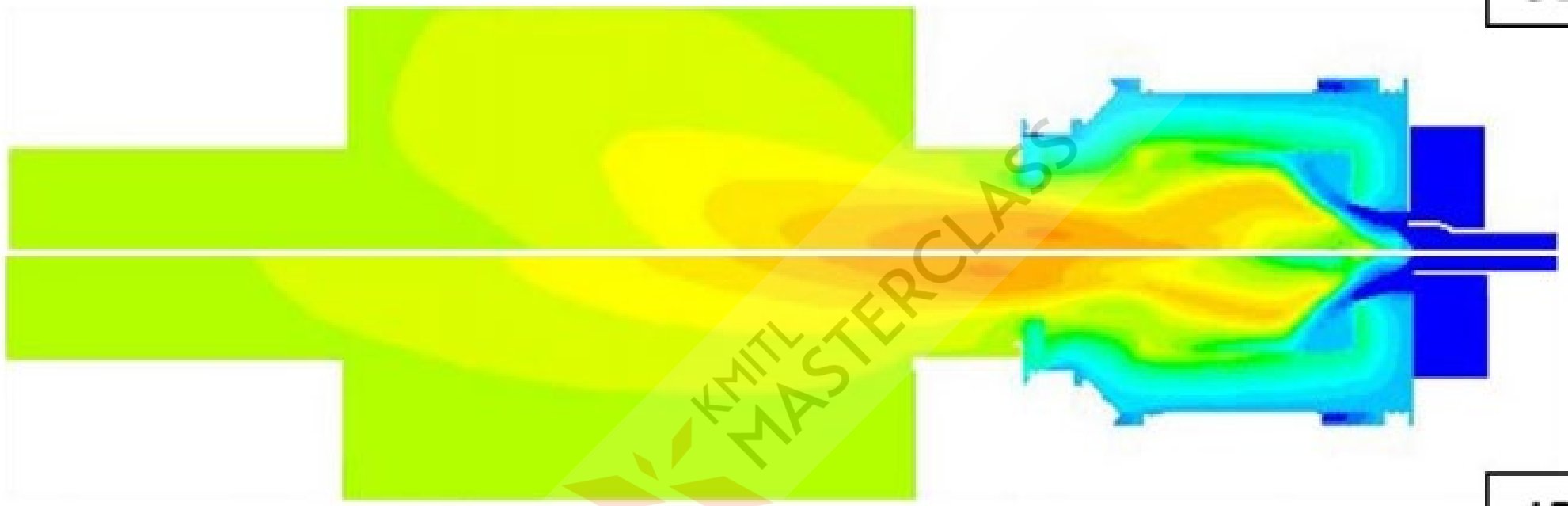


Aerodynamics



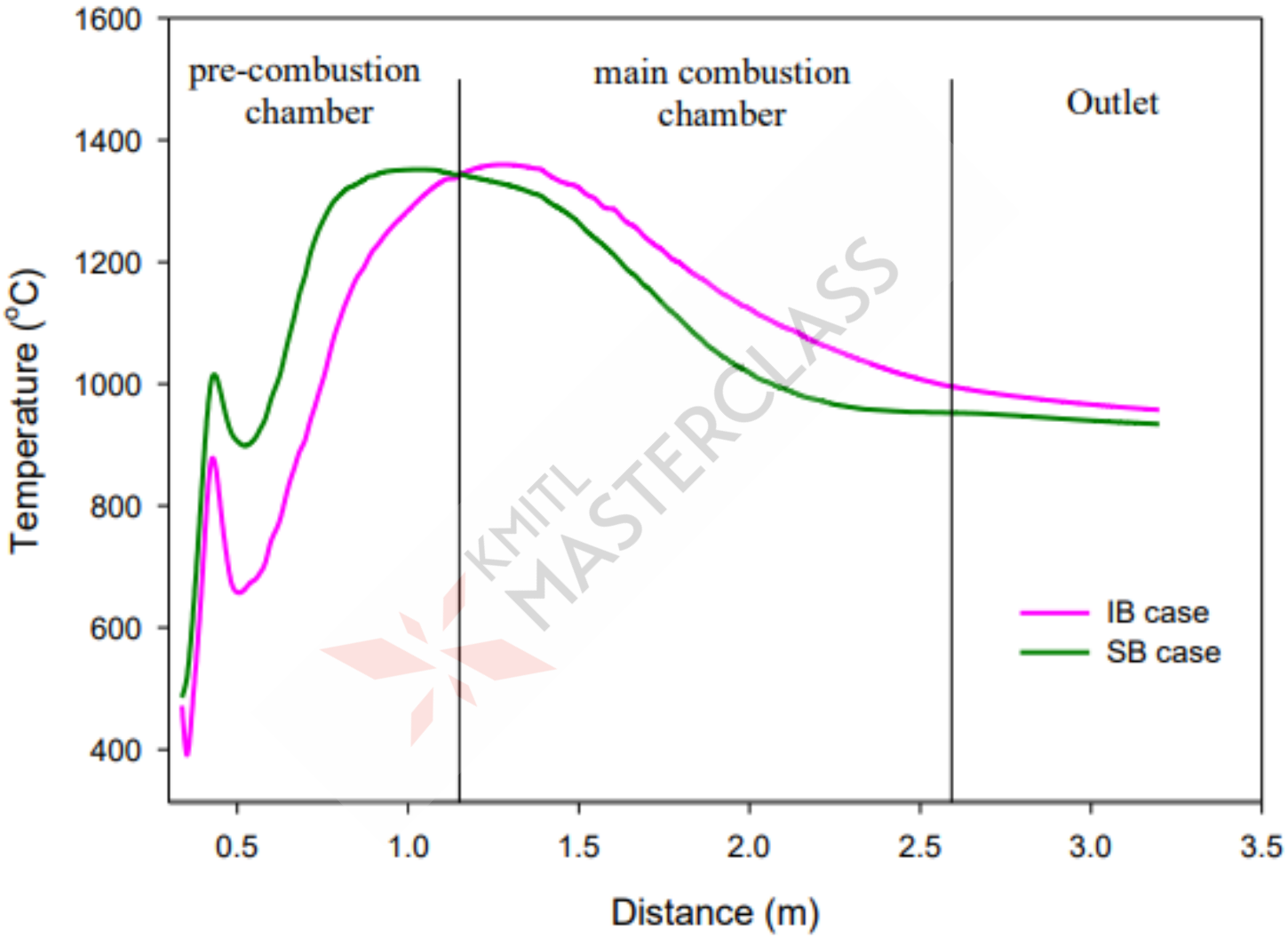

pre-combustion chamber
main combustion chamber
Outlet
Axial velocity (m/s)
Distance (m)
IB case
SB case
20
15
10
5
0
-5
0.5
1.0
1.5
2.0
2.5
3.0
3.5

SB case



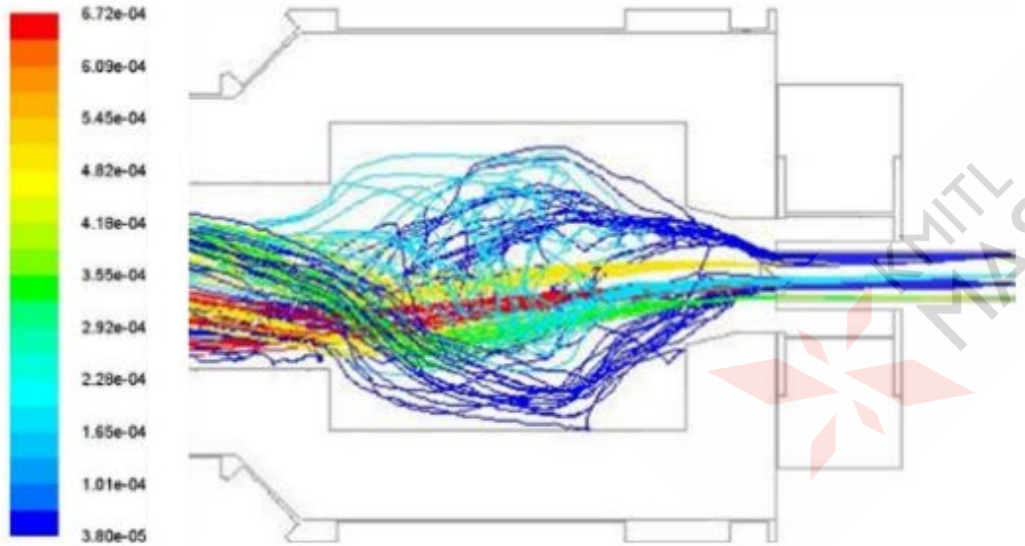
IB case

Temperature (°C)

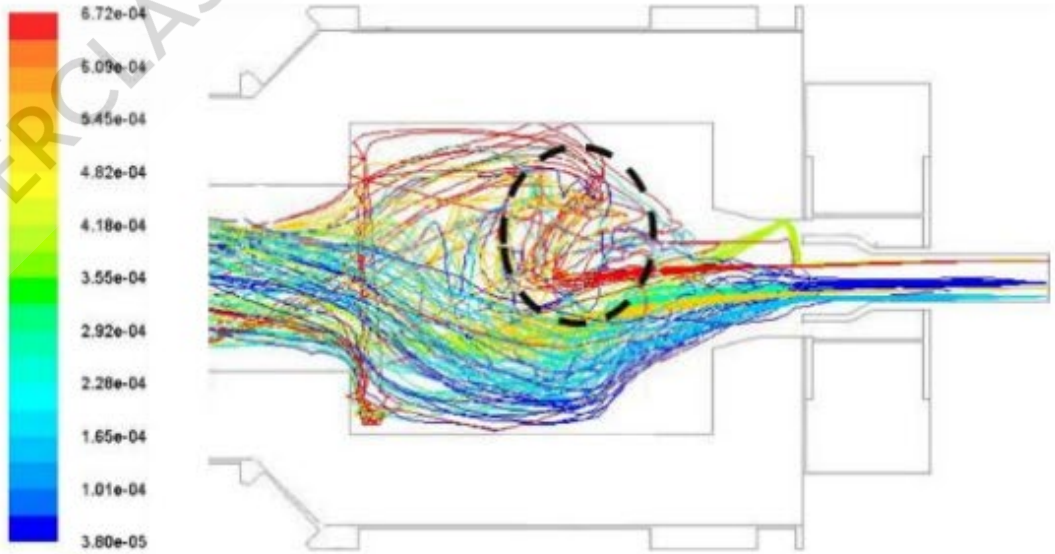

pre-combustion chamber
main combustion chamber
Outlet
Temperature (°C)
1600
1400
1200
1000
800
600
400
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Distance (m)
IB case
SB case

Particle trajectories

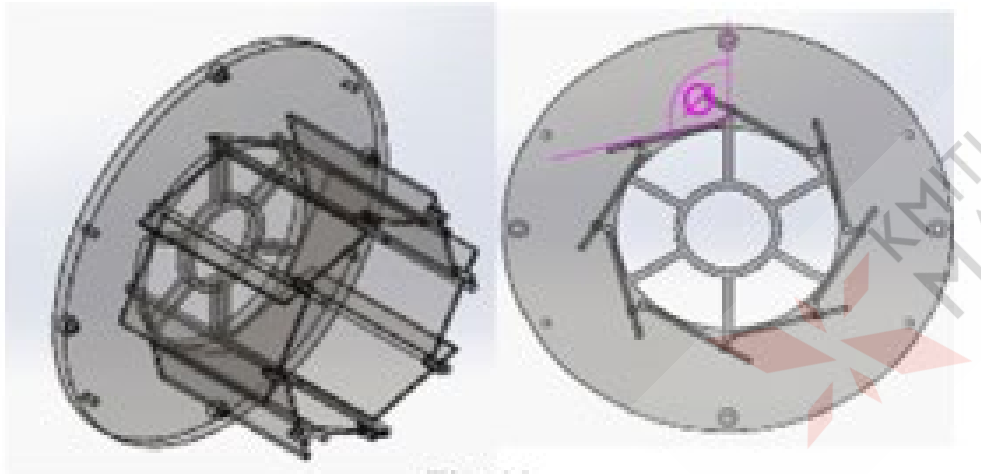
IB case



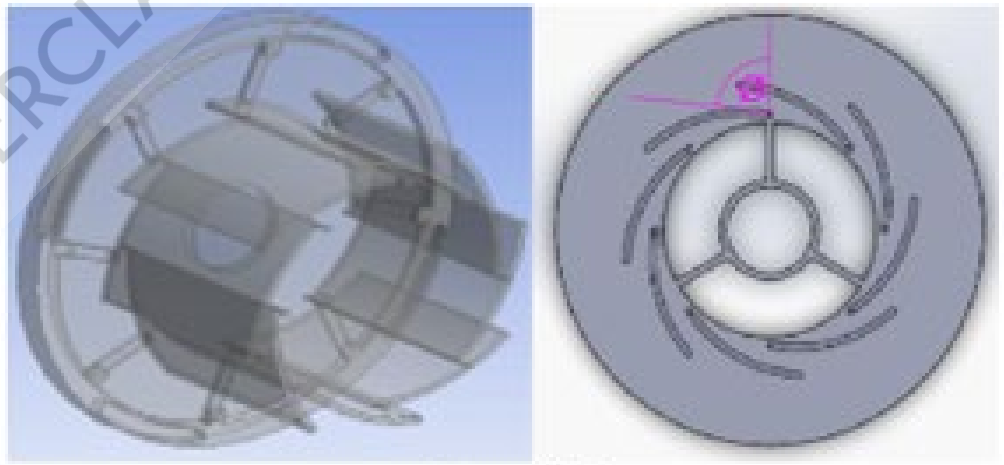
SB case



การปรับปรุง swirl box

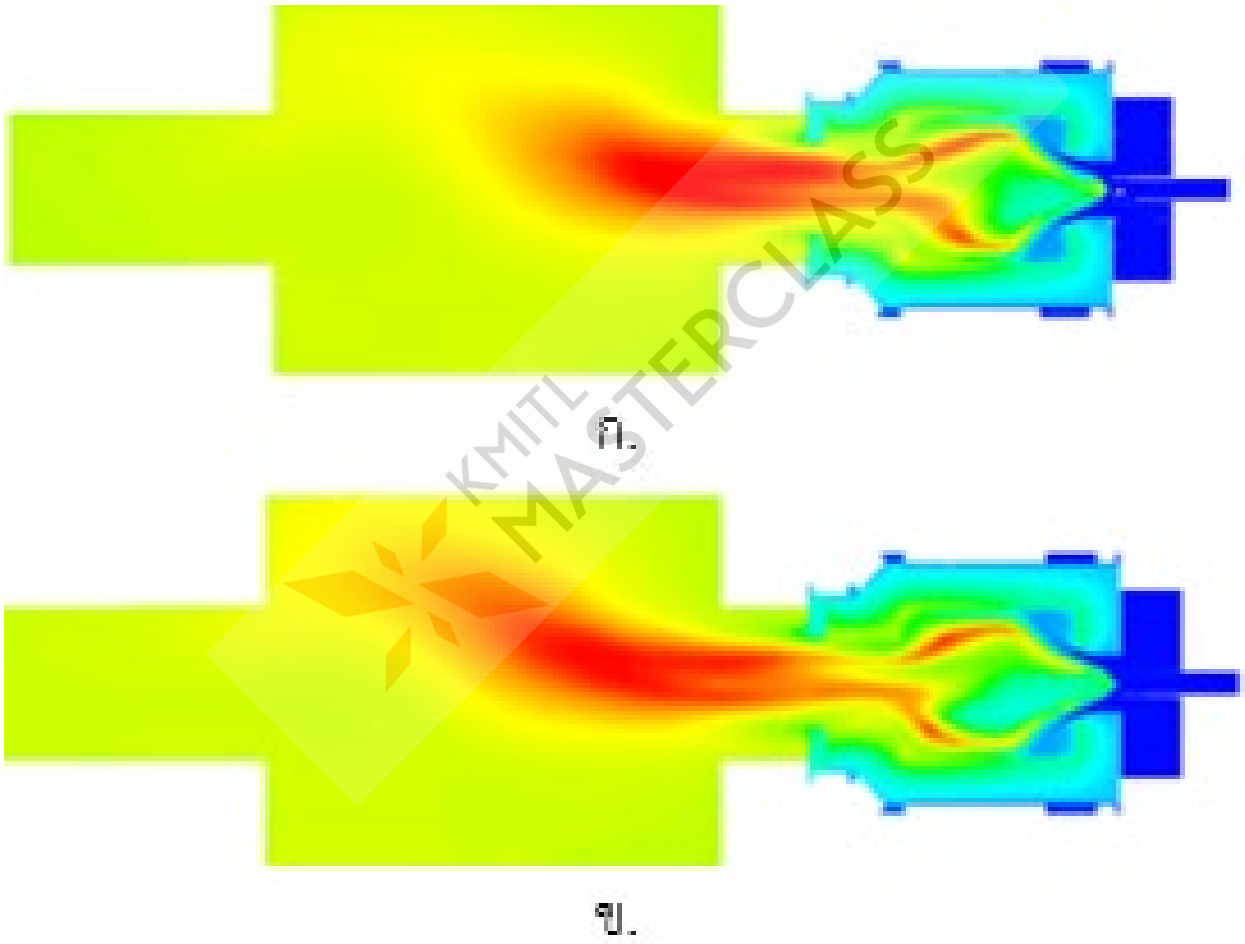


Flat-Vane

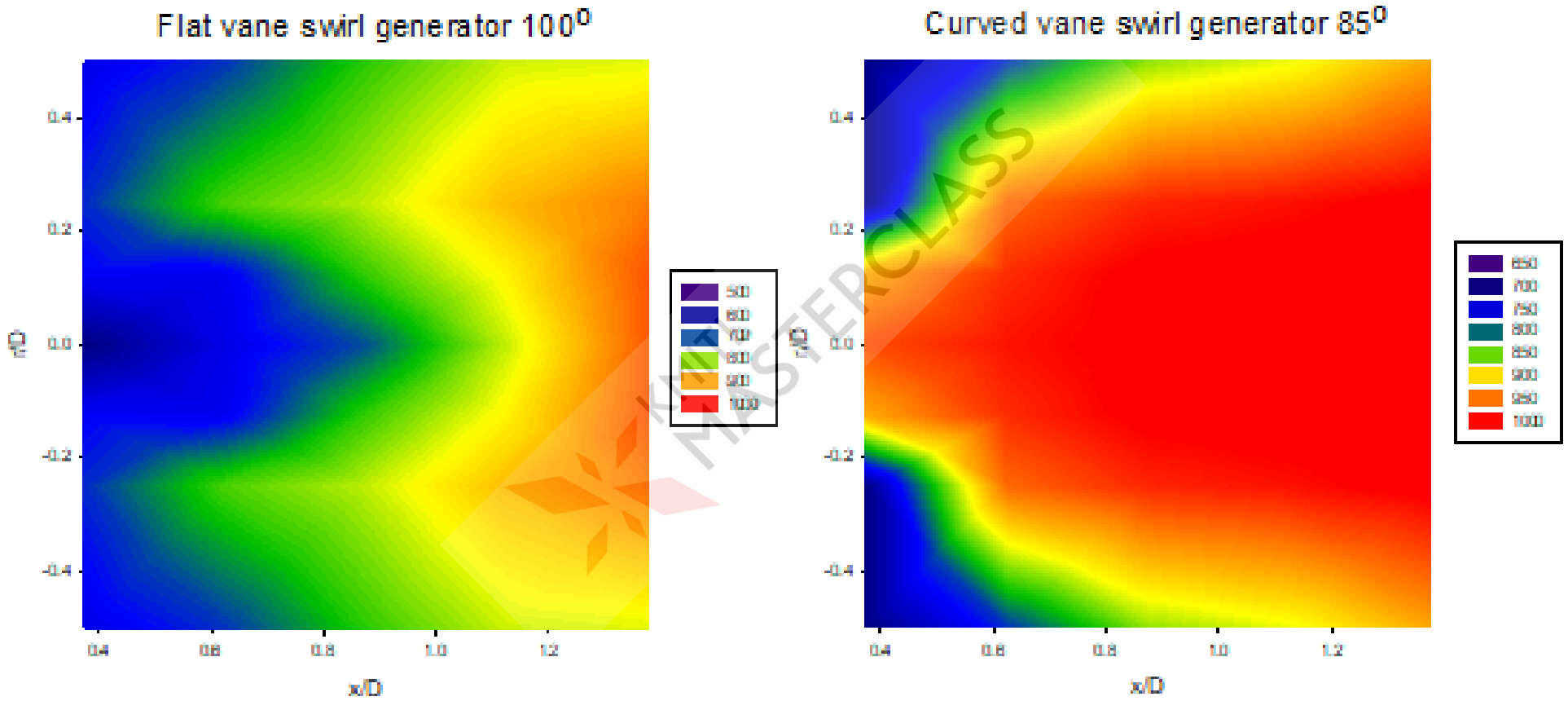


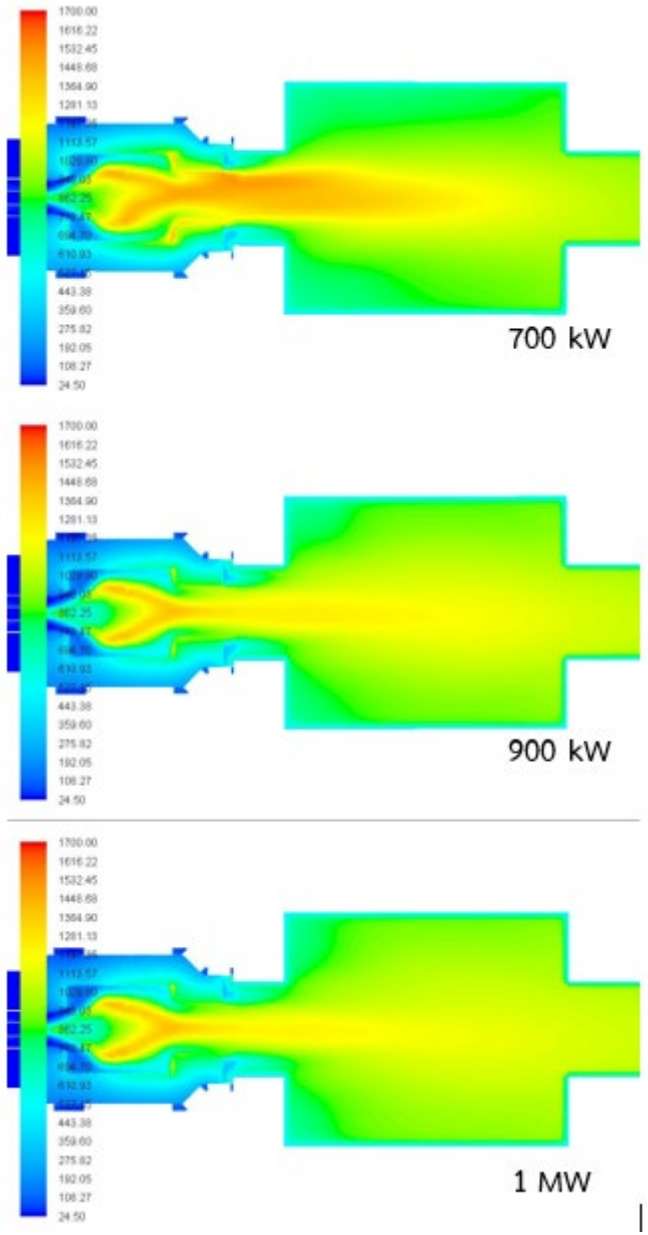
Curved-Vane

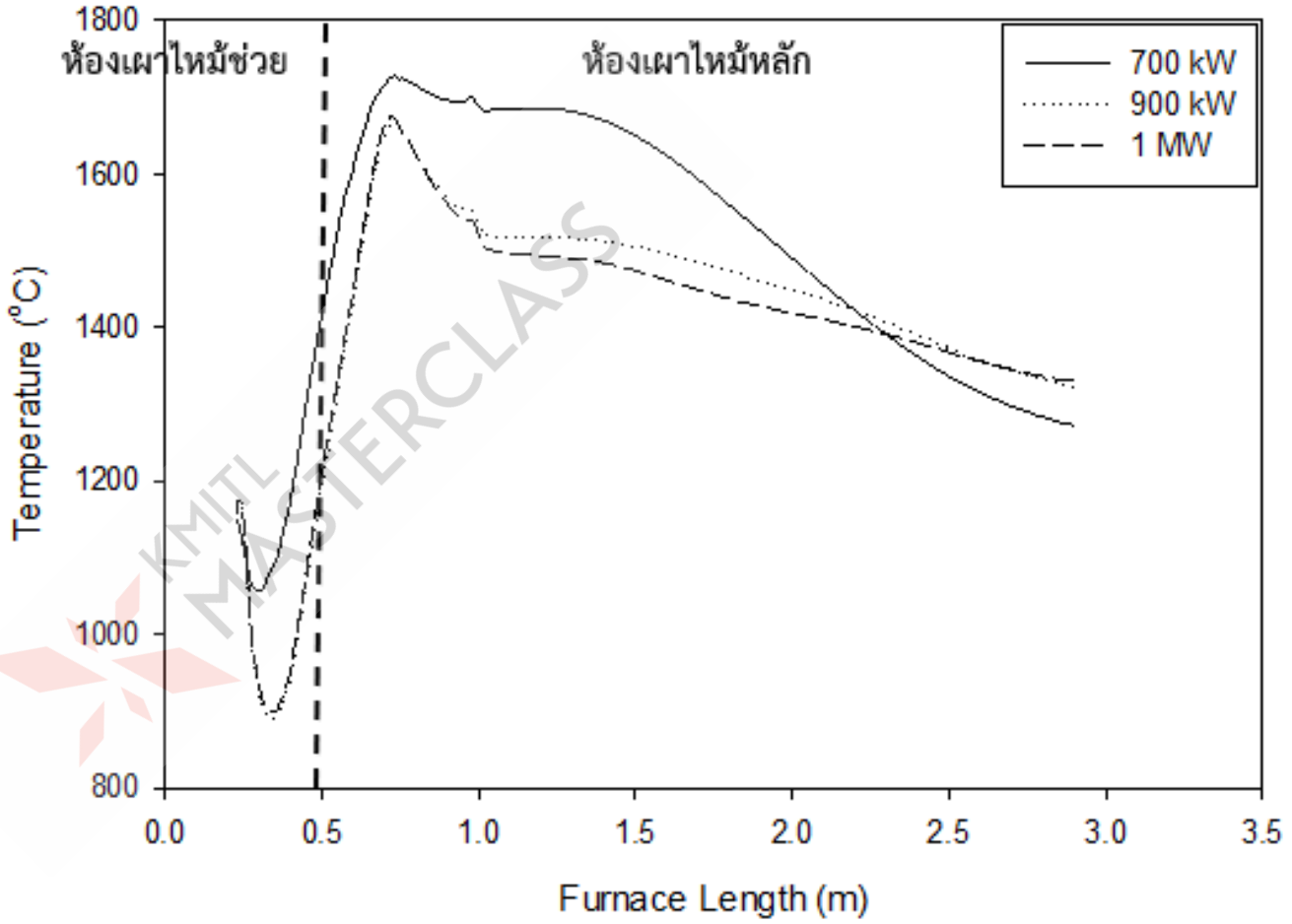
Temperature distribution : flat vane vs curved vane



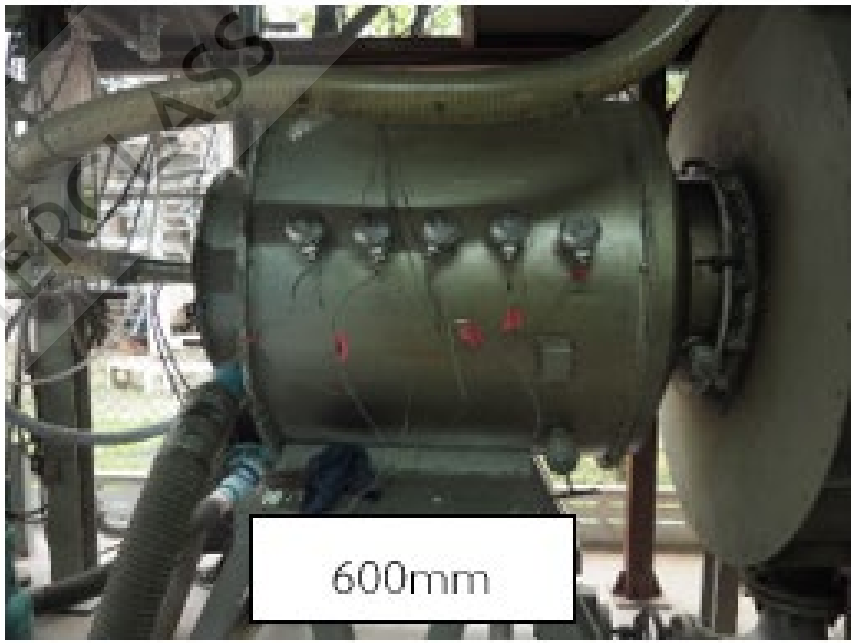
การกระจายอุณหภูมิ

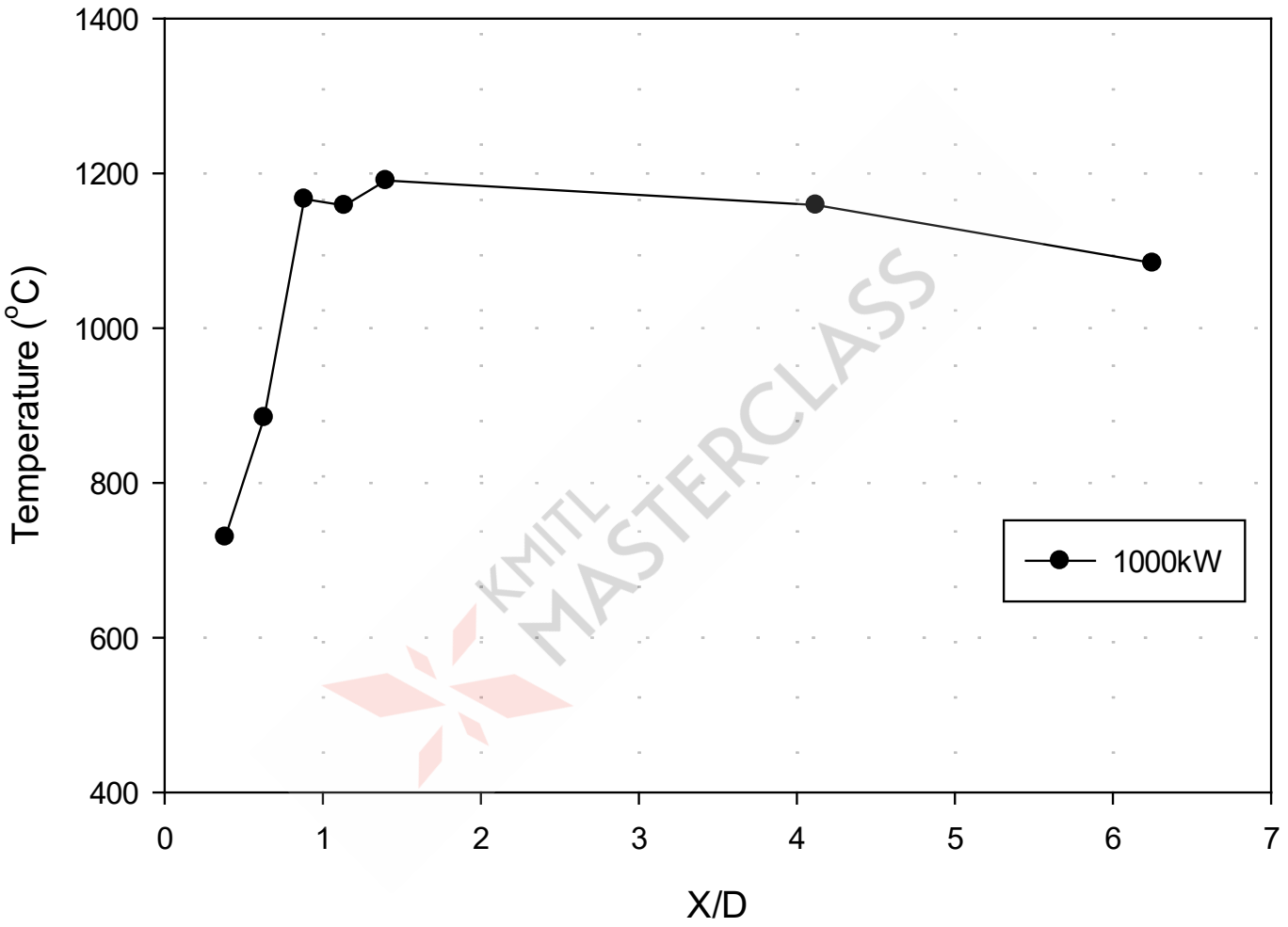


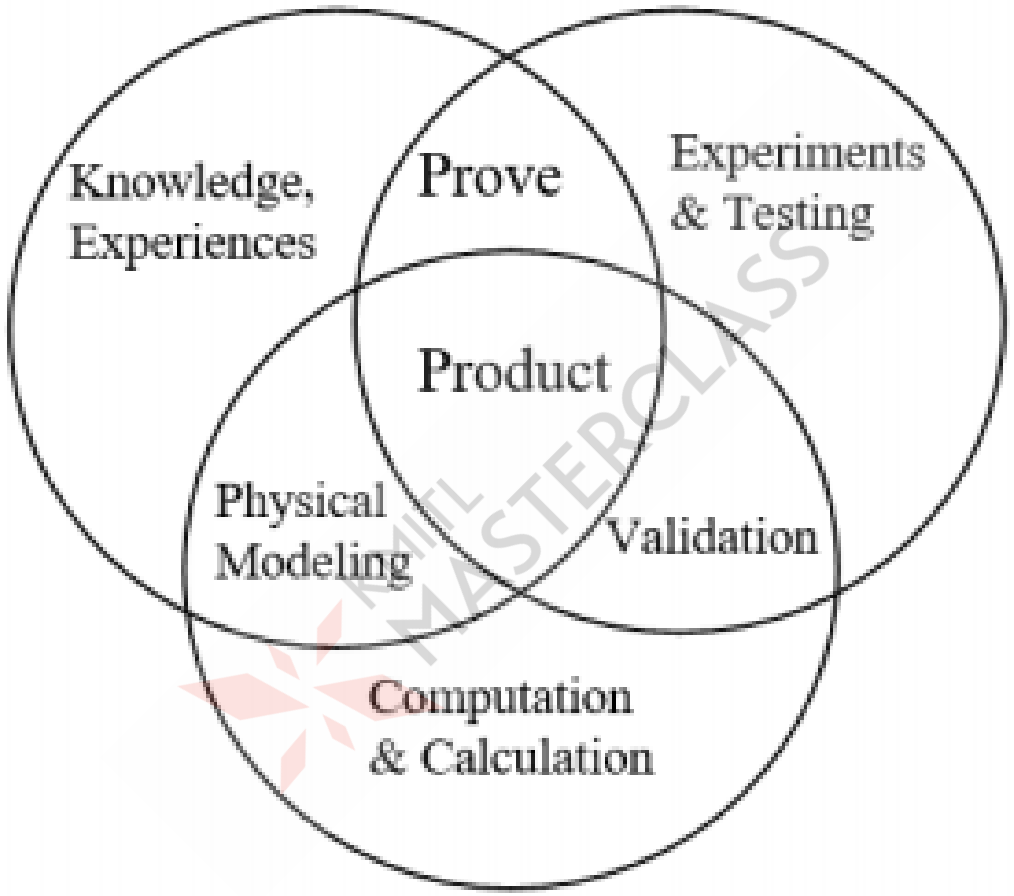




การเพิ่มขนาดห้องเผาไหม้ล่วงหน้า




1400
1200
1000
800
600
400
Temperature (°C)
0
1
2
3
4
5
6
7
X/D
1000kW

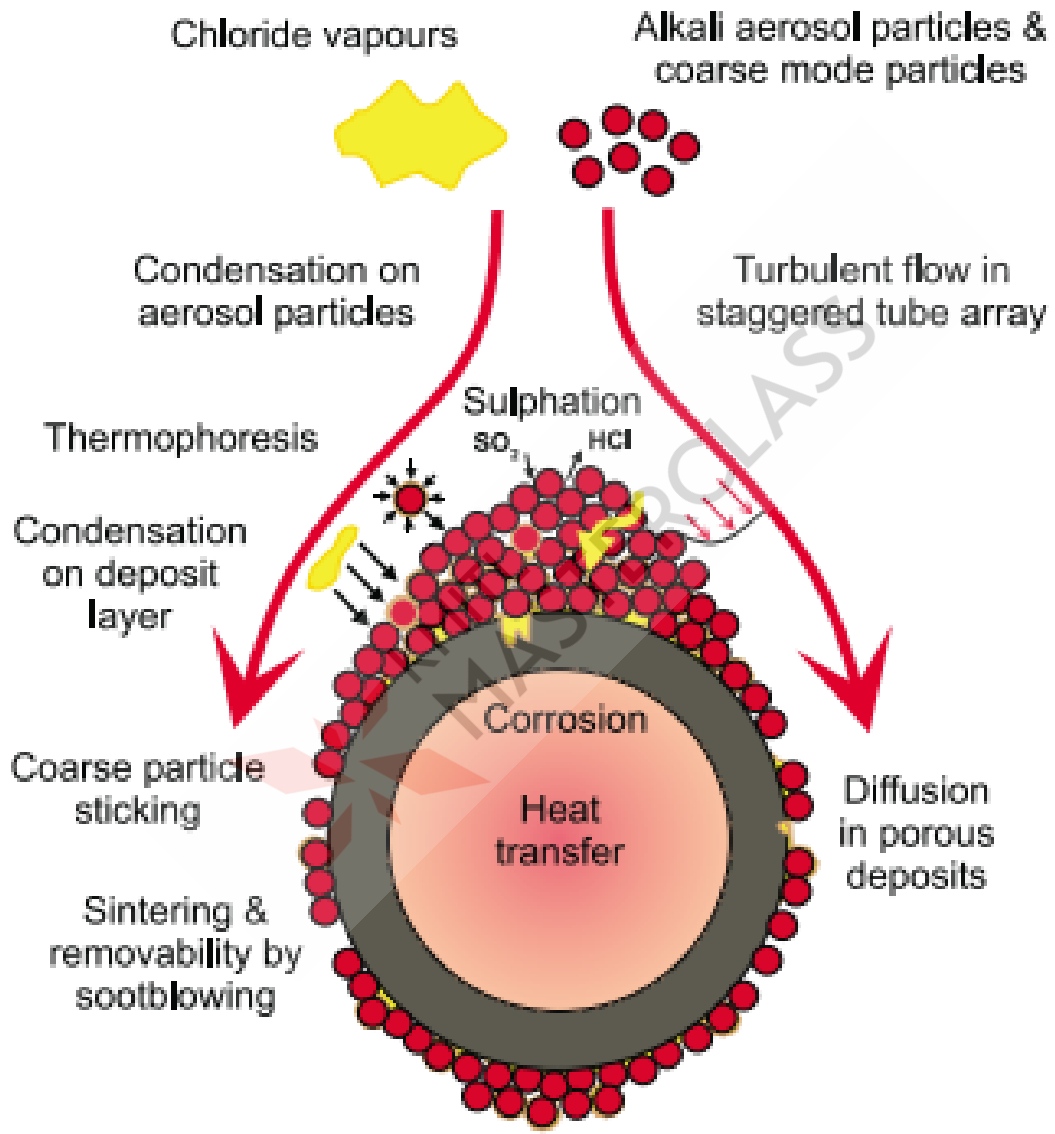

Knowledge,
Experiences
Prove
Experiments
& Testing
Product
Physical
Modeling
Validation
Computation
& Calculation

TYPICAL PROPERTIES OF SOLID FUELS

Property	Coal	Peat	Wood without bark	Bark	Forest residues (coniferous tree with needles)	Willow	Straw	Reed canary grass (spring harvested)	Olive residues
Ash content (d)	8.5-10.9	4-7	0.4-0.5	2-3	1-3	1.1-4.0	5	6.2-7.5	2-7
Moisture content, w-%	6-10	40-55	5-60	45-65	50-60	50-60	17-25	15-20	60-70
Net calorific value, MJ/kg	26-28.3	20.9-21.3	18.5-20	18.5-23	18.5-20	18.4-19.2	17.4	17.1-17.5	17.5-19
C, % (d)	76-87	52-56	48-52	48-52	48-52	47-51	45-47	45.5-46.1	48-50
H, % (d)	3.5-5	5-6.5	6.2-6.4	5.7-6.8	6-6.2	5.8-6.7	5.8-6.0	5.7-5.8	5.5-6.5
N, % (d)	0.8-1.5	1-3	0.1-0.5	0.3-0.8	0.3-0.5	0.2-0.8	0.4-0.6	0.65-1.04	0.5-1.5
O, % (d)	2.8-11.3	30-40	38-42	24.3-40.2	40-44	40-46	40-46	44	34
S, % (d)	0.5-3.1	<0.05-0.3	<0.05	<0.05	<0.05	0.02-0.10	0.05-0.2	0.08-0.13	0.07-0.17
Cl, % (d)	<0.1	0.02-0.06	0.01-0.03	0.01-0.03	0.01-0.04	0.01-0.05	0.14-0.97	0.09	0.1*
K, % (d)	0.003	0.8-5.8	0.02-0.05	0.1-0.4	0.1-0.4	0.2-0.5	0.69-1.3	0.3-0.5	30*
Ca, % (d)	4-12	0.05-0.1	0.1-1.5	0.02-0.08	0.2-0.9	0.2-0.7	0.1-0.6	9	

d=dry basis
*= in ash

CEN-335 – Solid biofuels, Fuel specifications and classes. March 2003.


Chloride vapours
Alkali aerosol particles & coarse mode particles
Condensation on aerosol particles
Turbulent flow in staggered tube array
Thermophoresis
Sulphation
SO_2
HCl
Condensation on deposit layer
Corrosion
Heat transfer
Coarse particle sticking
Diffusion in porous deposits
Sintering & removability by sootblowing

- Steam Boiler | IVAR | Working – YouTube
- Understanding the Difference between Wetback & Dryback Boilers - SteamWorks – YouTube
- Boiler and perssure vessel maintenance service & Boiler Inspection Fee Boiler Efficiency Inspection and Tune up Fee - Gmeengineers