

(A numerical analysis on the transient behavior of melt and slag in continuous casting tundish )



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dam & weir profile

open pouring



profile

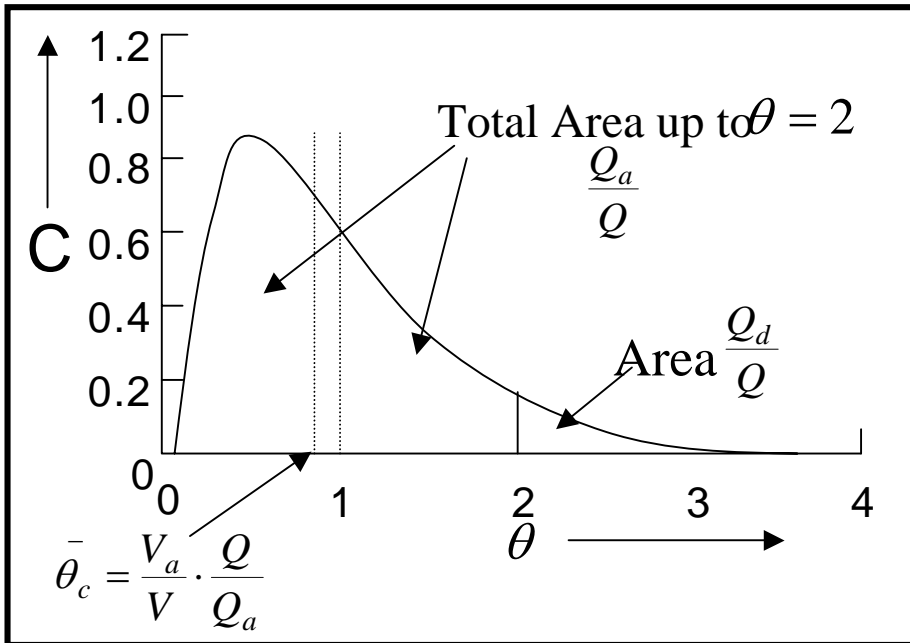


dam & weir profile



# RTD ( Residence Time Distribution )

- RTD (dead volume)
- (mixing volume)
- combined model



## Dead volume fraction

$$\frac{V_d}{V} = 1 - \frac{Q_a}{Q} \bar{\theta}_c$$

Where,

$$\bar{\theta}_c = \frac{\sum_{\theta=0}^2 C_i \theta_i}{\sum_{\theta=0}^2 C_i}$$

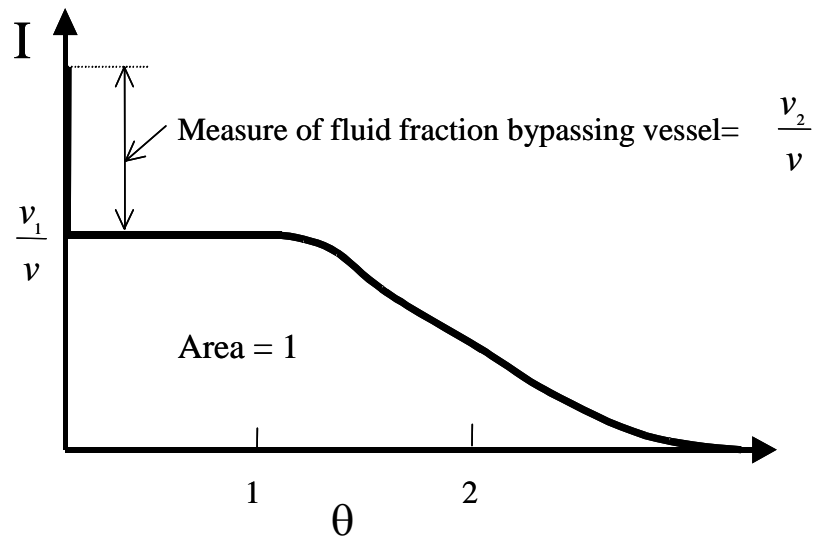
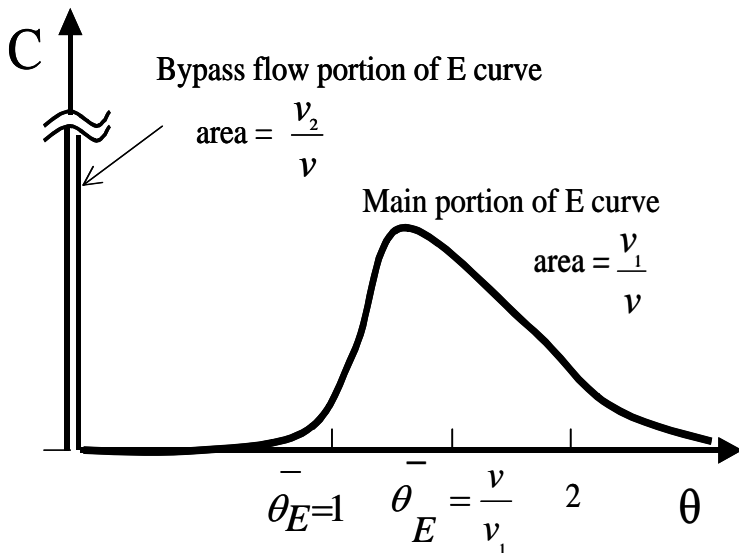
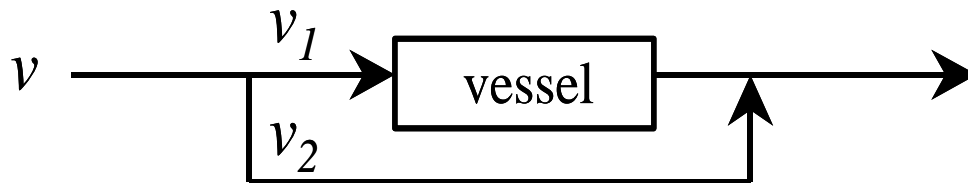
Dimensionless average mean residence time up to  $\theta = 2$

$$\frac{Q_a}{Q} = \sum_{\theta=0}^2 C_i \Delta\theta$$

The area under C-curve from  $\theta = 0$  to 2

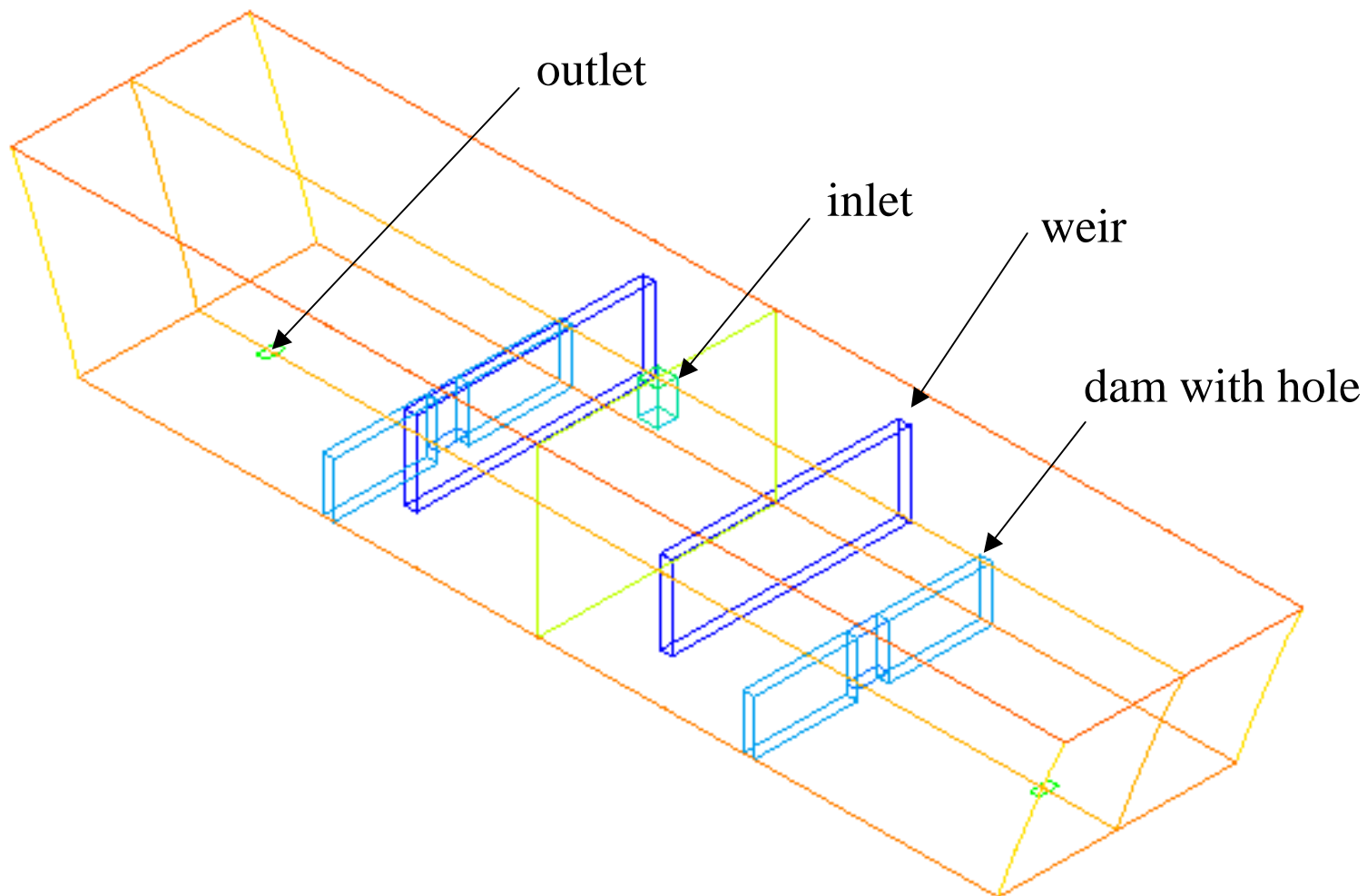


# I curve(I(t):Internal age distribution function)





# Tundish configuration





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## Configuration of tundish for computation

hole-dam size(mm)	Hole height	70
	Hole width	220
	Thickness	80
weir size(mm)	Weir height	600
	Weir from bottom	350
	Center ~ Weir	940
	Thickness	80
Bottom length(mm)	total	6476.4
Top length(mm)	total	7424.4
Height of melt(mm)		1200
Casting speed(mm/min)		1400
Flow rate of ladle(L/min)		837.2
Slab size(mm)	Length side	1300
	Width side	230



### Dam & weir profile for computation

	case 1	case 2	case 3	case 4	case 5
Dam height	291	291	291	291	291
Weir ~ Dam	300	400	500	600	700
	case 6	case 7	case 8	case 9	case 10
Dam height	351	351	351	351	351
Weir ~ Dam	300	400	500	600	700
	case 11	case 12	case 13	case 14	case 15
Dam height	390	390	390	390	390
Weir ~ Dam	300	400	500	600	700



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open pouring

1. Dam height : 390mm, dam ~ weir : 500mm
2. Dam height : 290mm, dam ~ weir : 500mm

### < Assumption >



가 particle



open pouring





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## *Governing Equation*

*Continuity Equation*

$$\frac{\partial}{\partial x_i}(\rho u_i) = 0$$

*Momentum Equation*

$$\rho u_k \frac{\partial u_j}{\partial x_k} = -\frac{\partial P}{\partial x_k} + \frac{\partial}{\partial x_i} \left[ \mu \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \right] + F_i$$

*Turbulence Model*

*k - ε two equation model*

*Concentration Equation*

$$\frac{\partial}{\partial t}(\rho C) + \frac{\partial}{\partial x_i}(\rho \mu_i C) = \frac{\partial}{\partial x_i} \left( \rho D_e \frac{\partial C}{\partial x_i} \right)$$

C : Conc. of tracer,  $D_e$  : Effective mass diffusion coeff.



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## *Governing Equation*

*Continuity Equation*

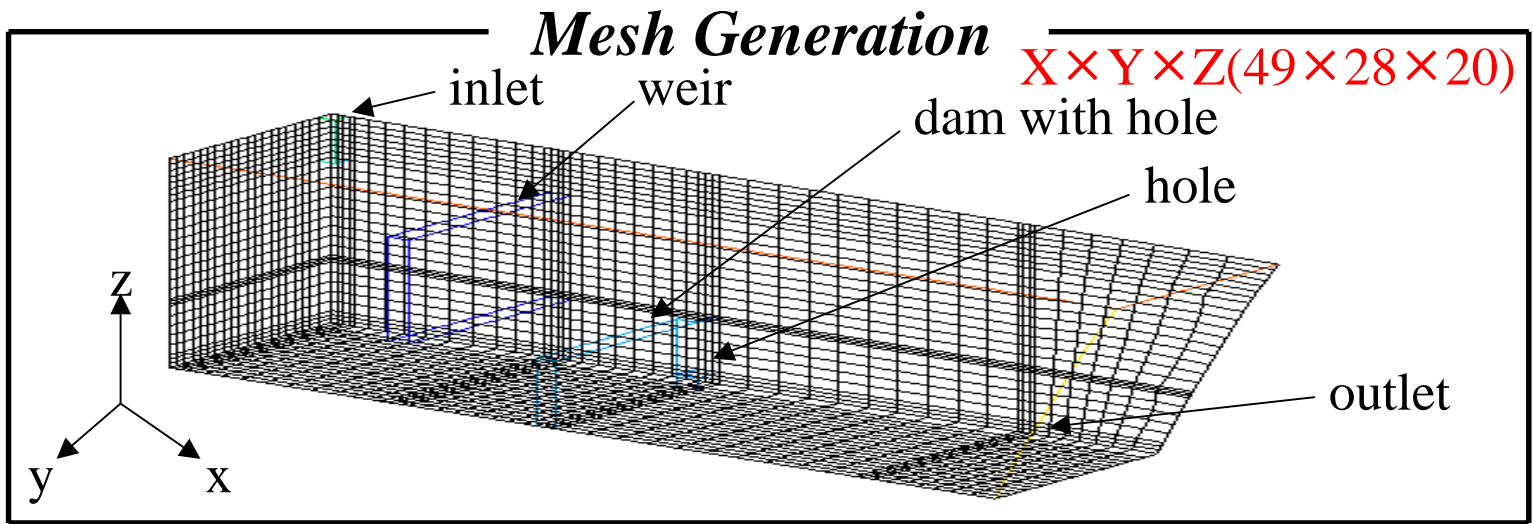
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho V) = 0$$

*Momentum Equation*

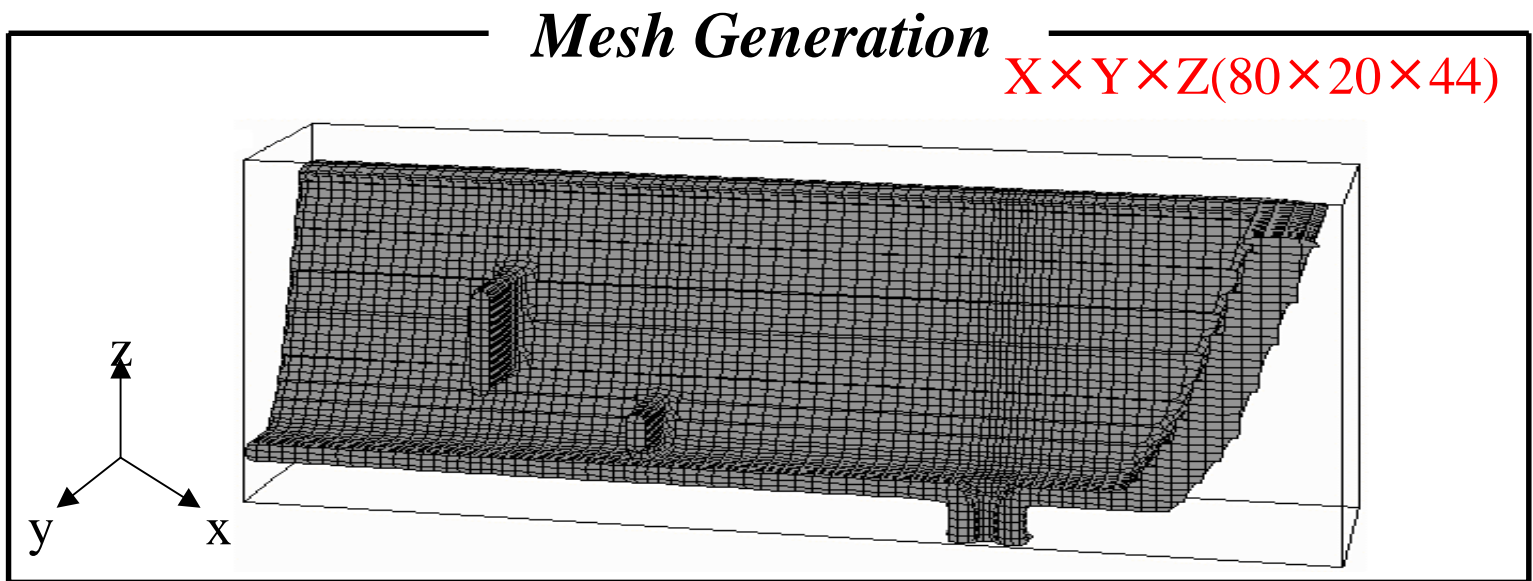
$$\rho \frac{\partial V}{\partial t} = \rho g - \nabla p + \nabla \cdot \tau_{ij}$$

*Viscous-dissipation function*

$$\Phi = \mu \left[ 2 \left( \frac{\partial u}{\partial x} \right)^2 + 2 \left( \frac{\partial v}{\partial y} \right)^2 + 2 \left( \frac{\partial w}{\partial z} \right)^2 + \left( \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z} \right)^2 + \left( \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right)^2 \right]$$



Grid system using body fitted coordinate system ( steady )



Grid system using rectangular mesh ( unsteady )



## **(steady state)**

- **(Dye injection experiment)**
- **Velocity profile**
- **RTD curve & Dead volume fraction**
- **I curve (internal age distribution curve)**



## **(unsteady state)**

- **( )**
- **Slag behavior & slag size distribution**



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Dam height : 390mm, dam-weir : 500mm



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5



10



15



20



25



30



40

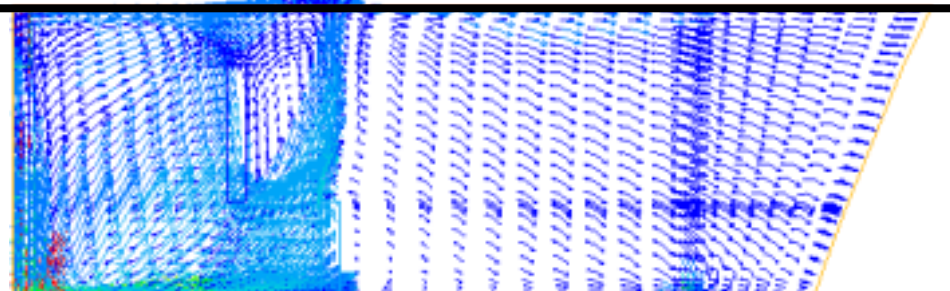


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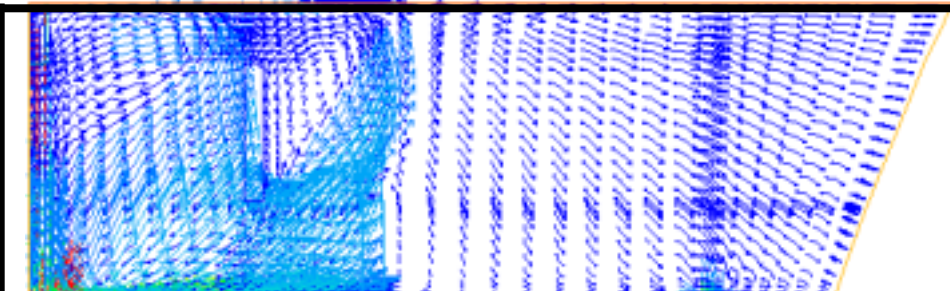


# *Velocity Profiles*

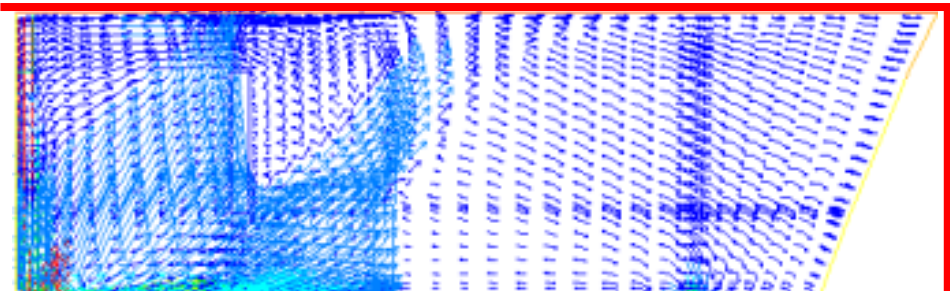
## Dam Height : 390mm



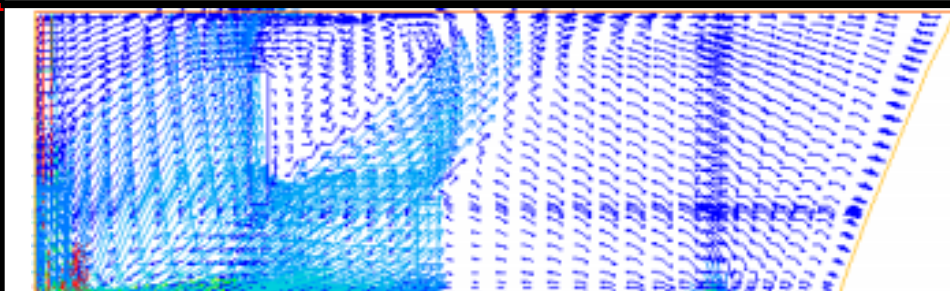
Dam-weir : 300mm



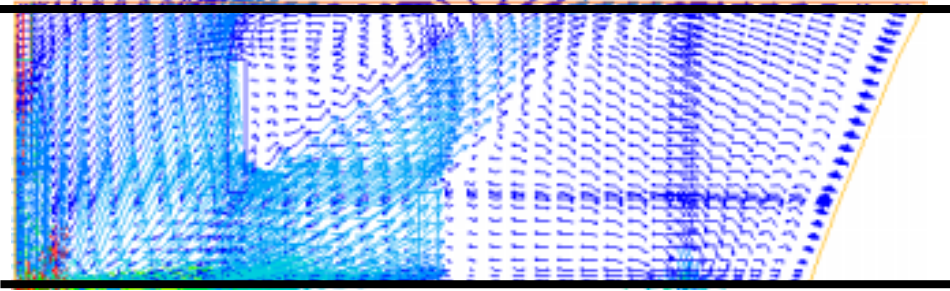
Dam-weir : 400mm



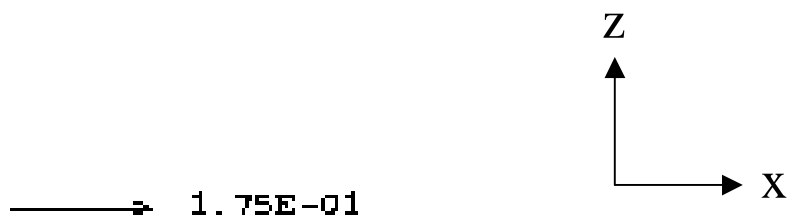
Dam-weir : 500mm



Dam-weir : 600mm



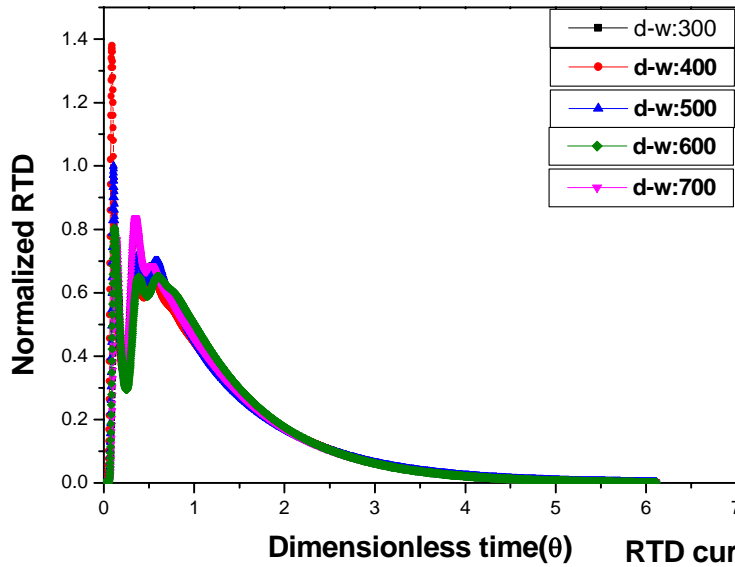
Dam-weir : 700mm



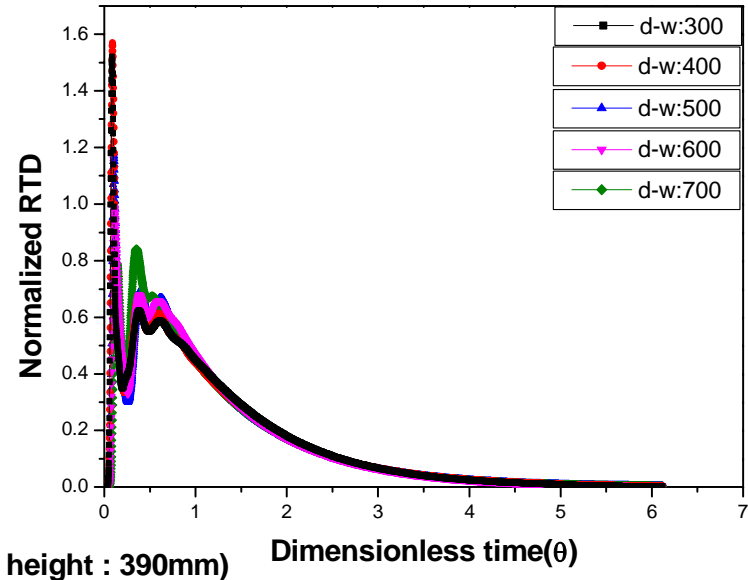


# RTD Curves

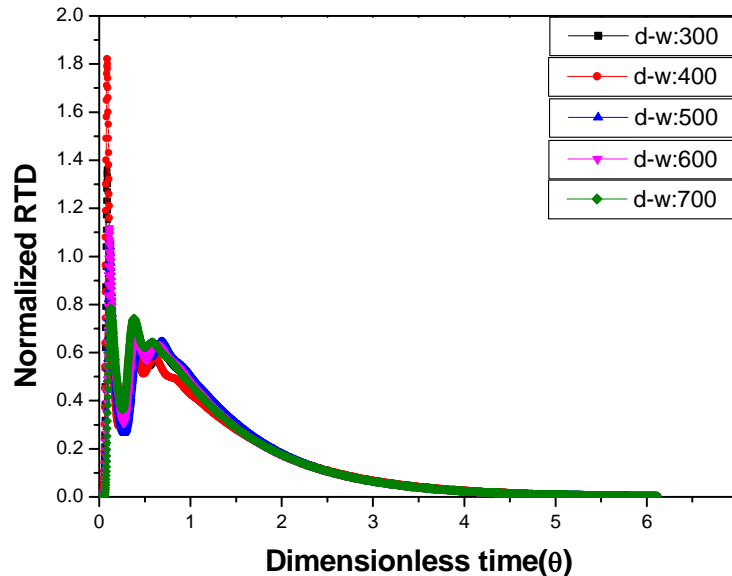
RTD curve(dam height: 291mm)



RTD curve(dam height : 351mm)

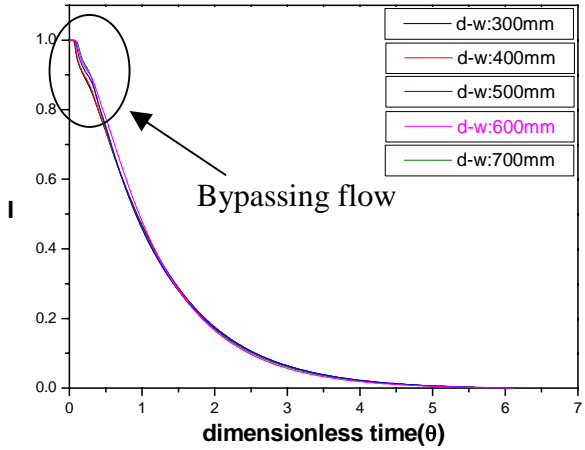


RTD curve(dam height : 390mm)

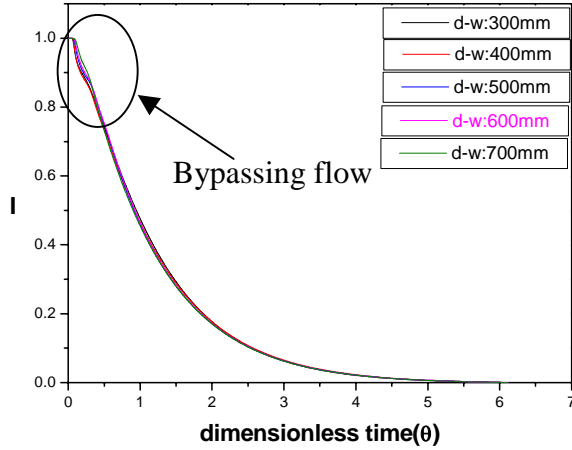




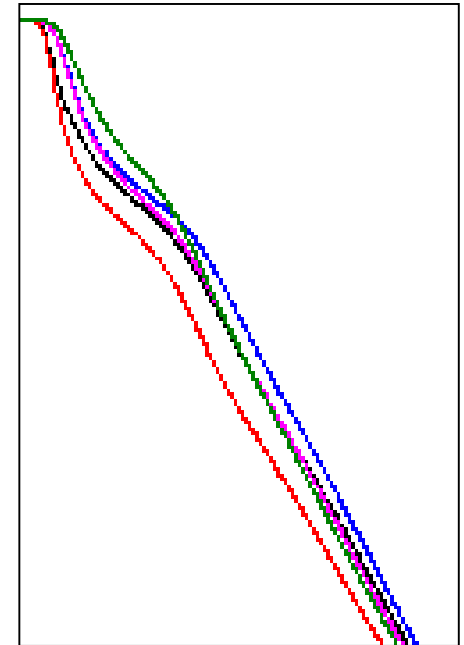
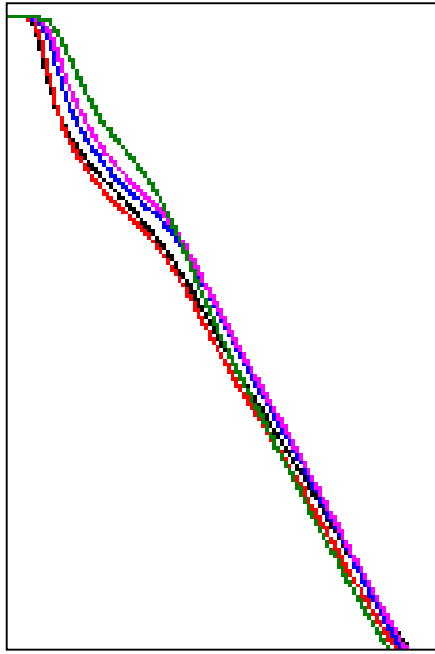
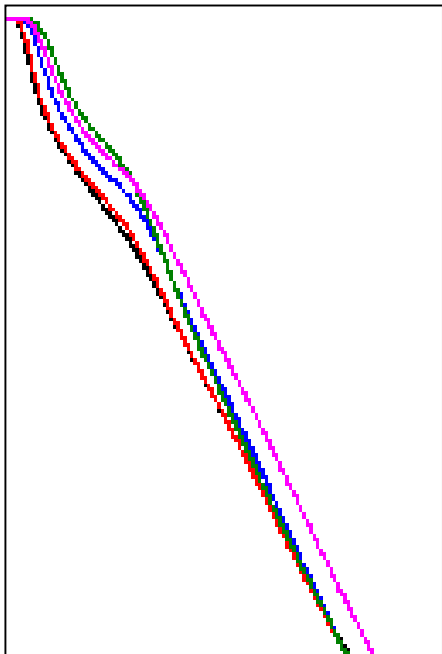
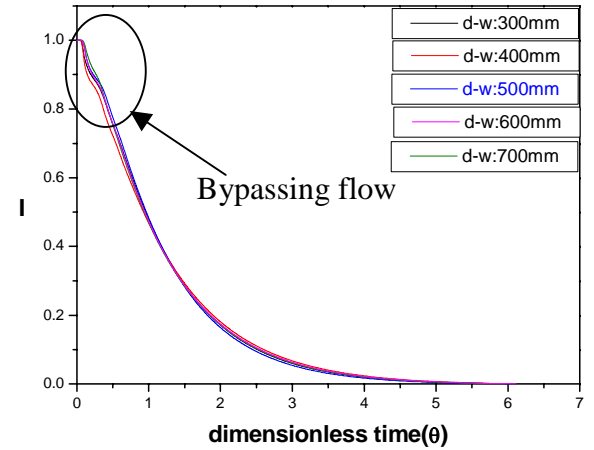
I curve(Dam Height : 290mm)



I curve(Dam Height : 350mm)



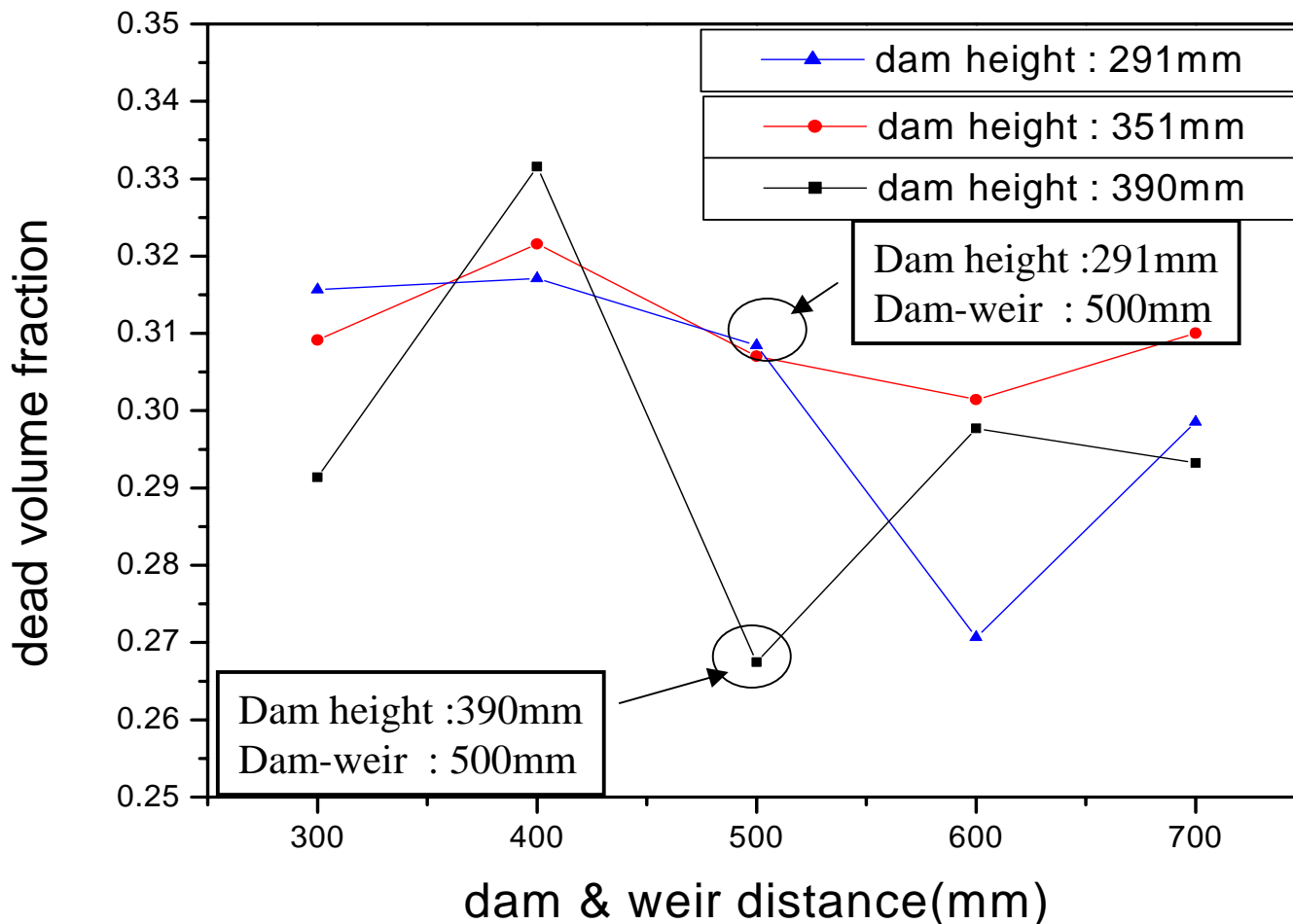
I curve(Dam Height : 390mm)







### Dead volume fraction





## **open pouring**

**1.**

**2.**

**- : 10~100micro meter slag particle      100**



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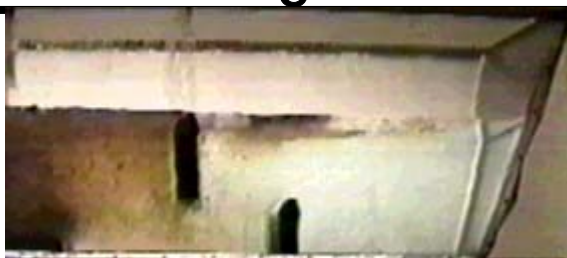
9



13



17



21



25



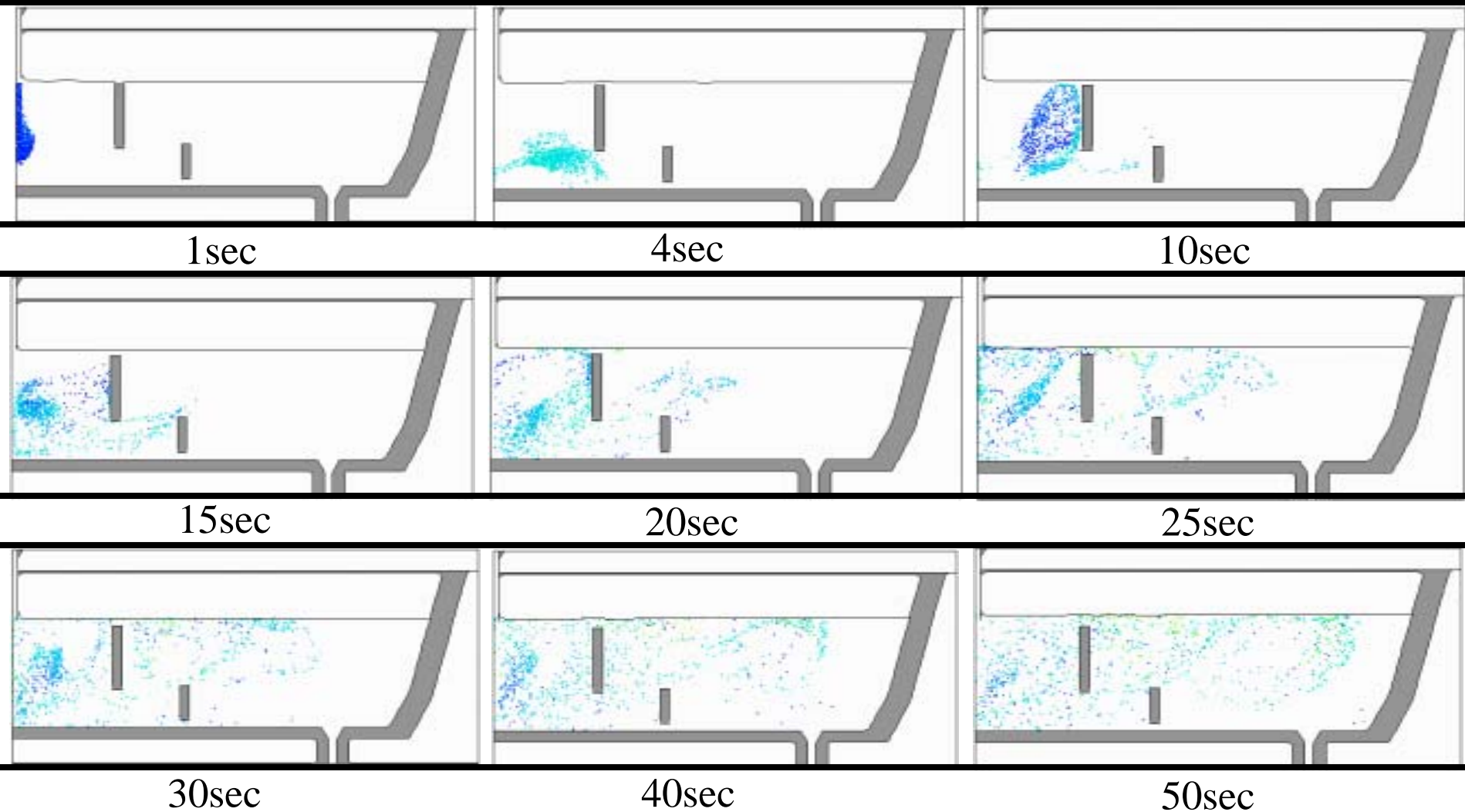
29



33

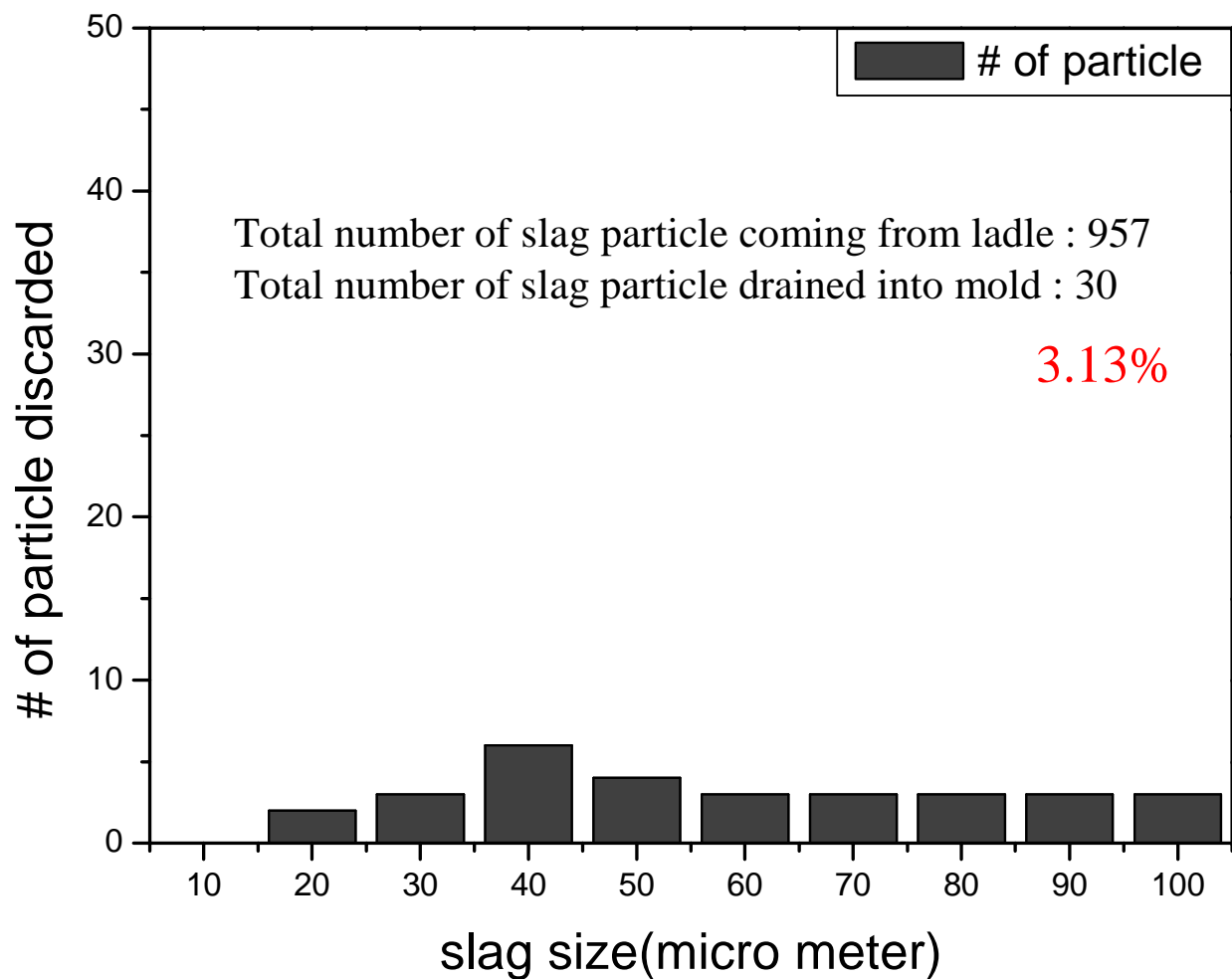


Dam height : 390mm, Dam~Weir :500mm



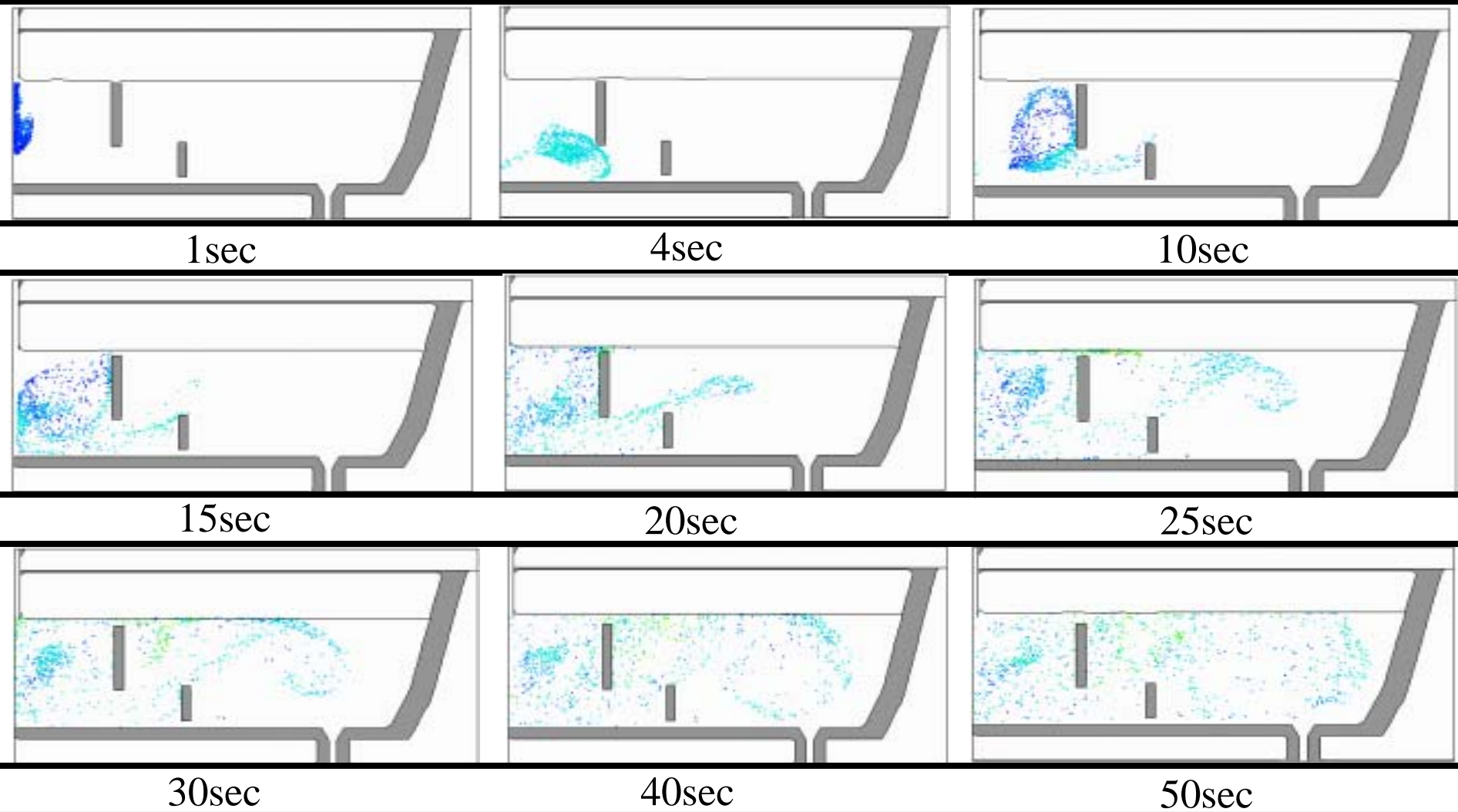


Dam Height : 390mm, Dam~Weir : 500mm



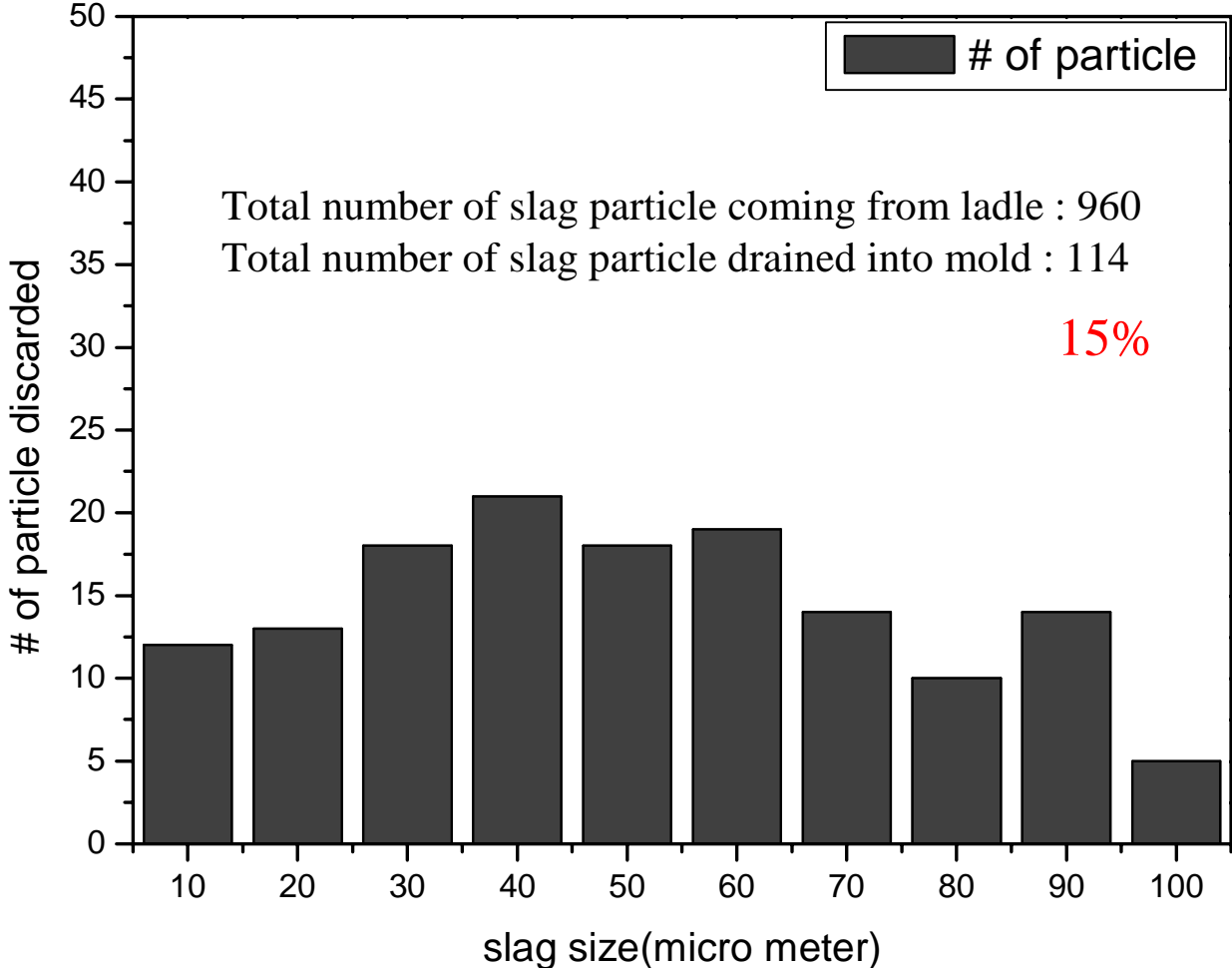


Dam Height : 290mm, Dam~Weir : 500mm





Dam Height : 290mm, Dam~Weir : 500mm





1. dam 가 dam weir

- | bypassing 가 가
- dam weir 500mm 가 가 390mm,

1.  
 2. Dam weir 500mm dam  
 390mm 290mm 15%  
 3.13%