Influence of horizontal curved water conveyance tunnel on hydraulic characteristics of side inlet/outlet

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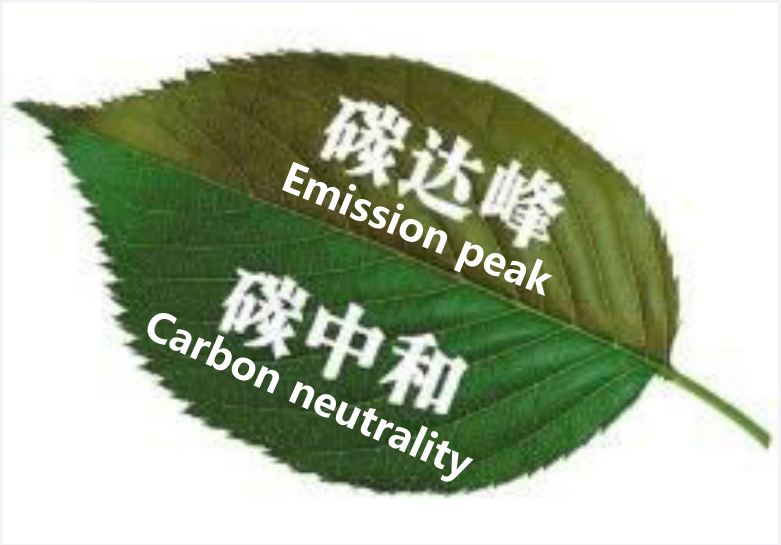
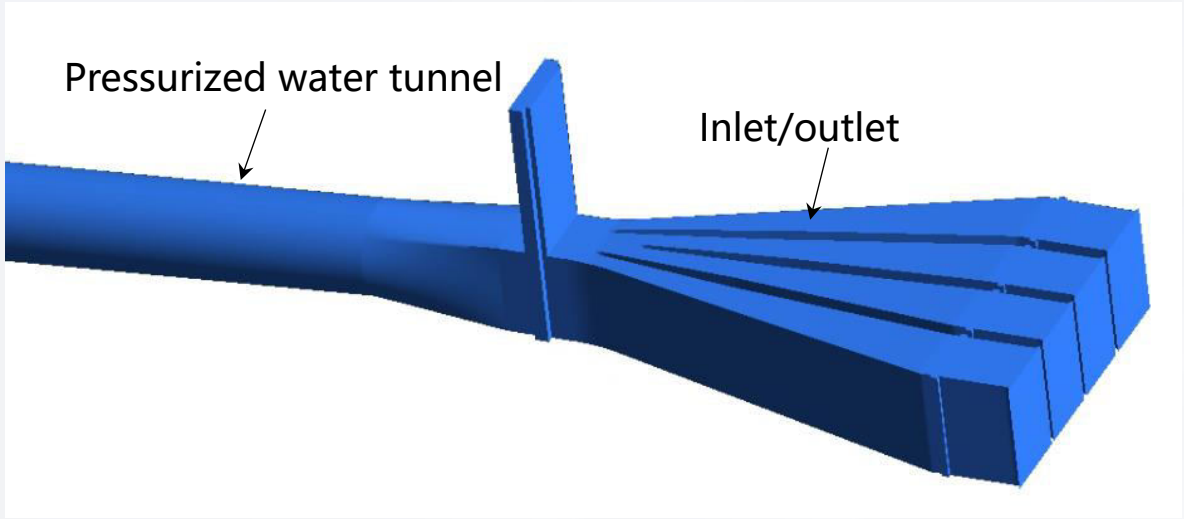
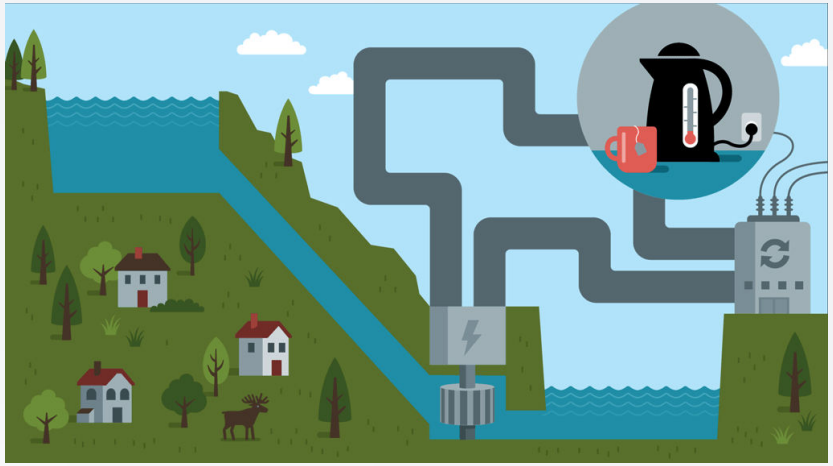
Introduction







Pumped-storage power station

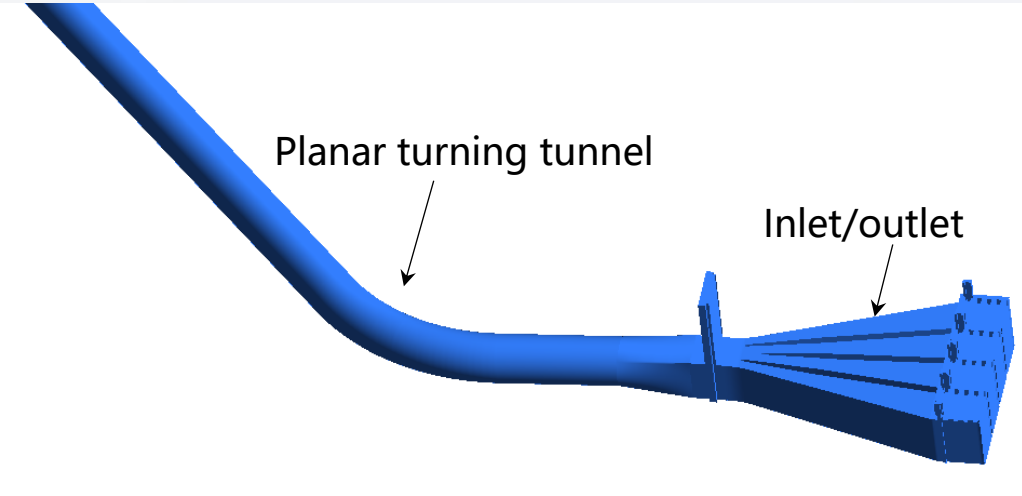
- Deviation of flow ratio of each orifice

$$d_Q = \left(\frac{Q_i}{Q_{total}}\right)_{max} - \left(\frac{Q_i}{Q_{total}}\right)_{min}, i = 1,2,3,4$$

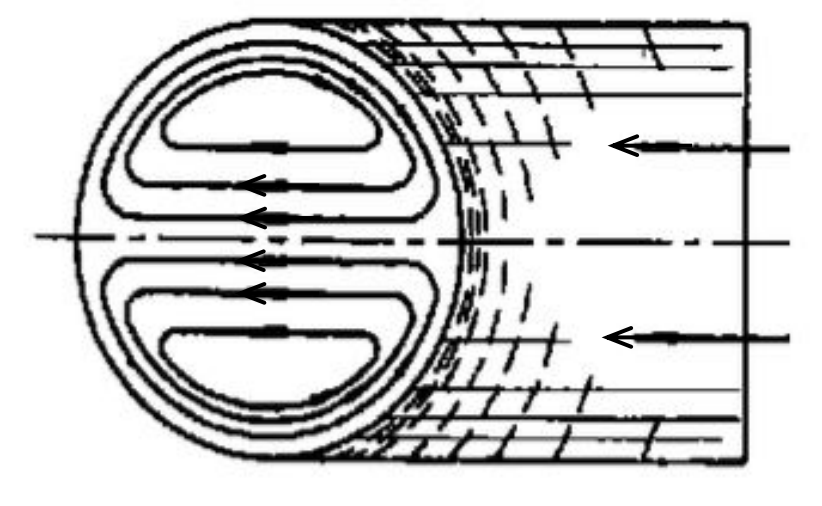
- Non-uniformity of flow velocity at trash rack section

$$v_{non-uniformity} = \frac{v_{max}}{\bar{v}}$$

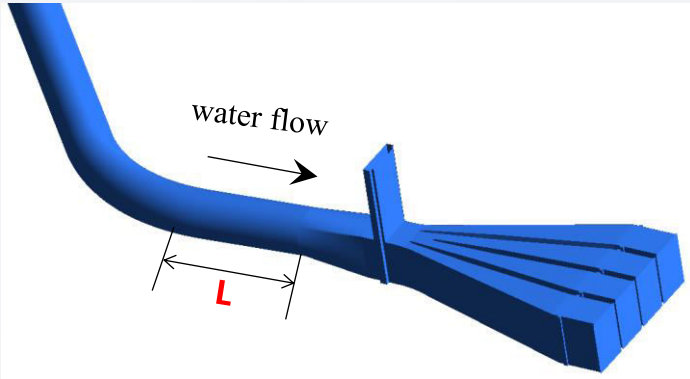
Introduction



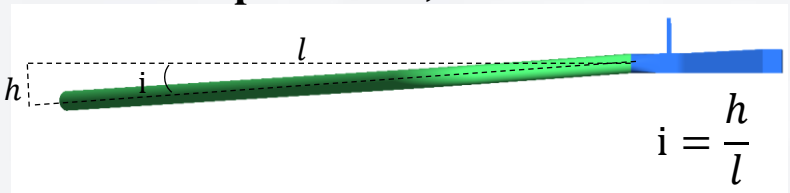
Dean vortices



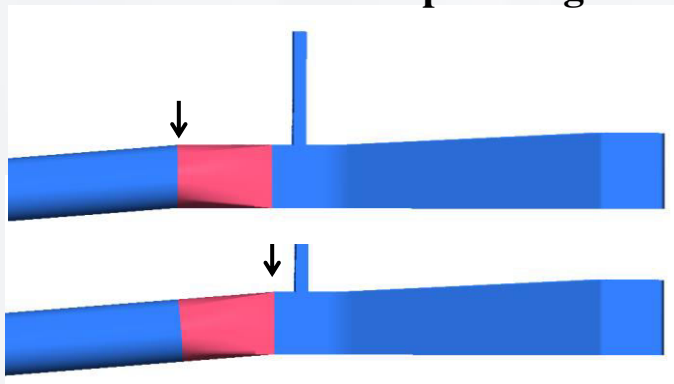
- **Straight section length：L=2.5D，5.6D，8.0D**



- **Tunnel slope：i=7%，8%**

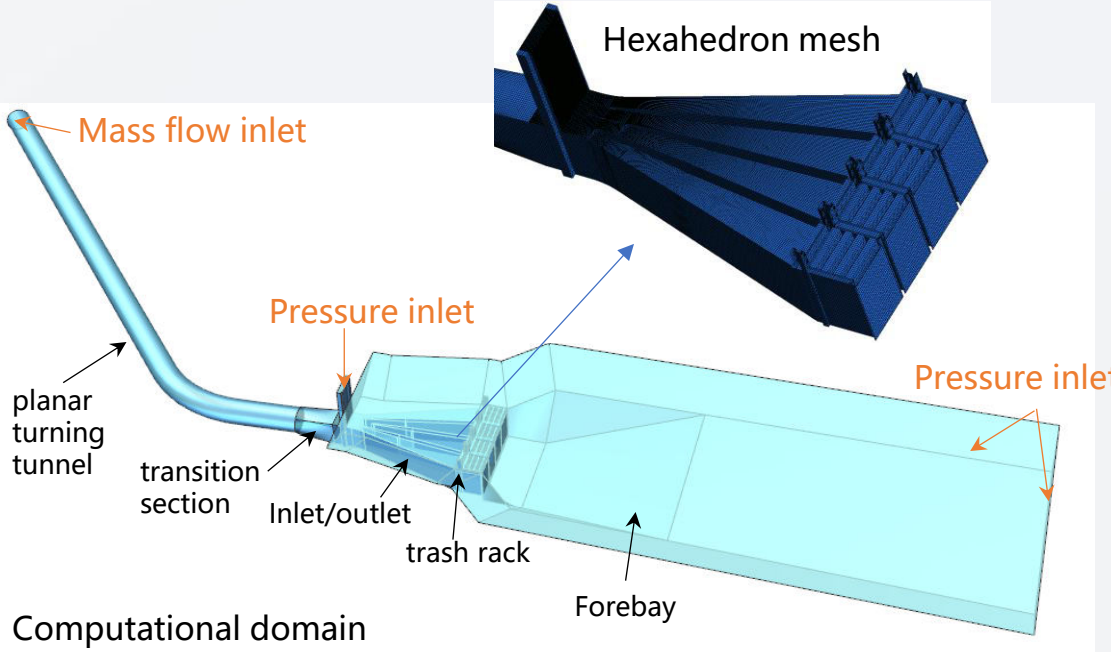


- **The location of the slope change**



Method

Numerical simulation



- **two-phase flow model**: VOF
- **turbulence model**: Reynolds Stress
- **Mesh number**: about 5 million

Model test

- **Model scope**: planar turning tunnel, Inlet/Outlet , Forbay

Reliability verification

Methods/Parameters	Flow distribution ratio	Non-uniformity of flow velocity (Vmax/Vave)
Numerical simulation	16.37%~34.47%	2.19~2.72
Model test	17.3%~33.11%	1.80~2.13

The numerical simulation results are basically consistent with the experimental results.

Results

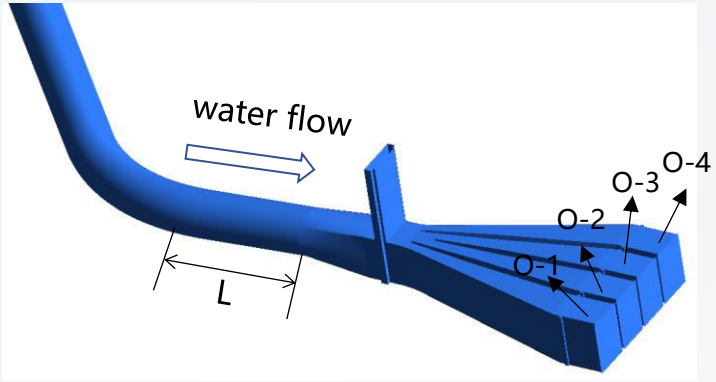
➢ The Influence of **planar turning tunnel** on hydraulic characteristics of inlet/outlet water

- Flow distribution ratio of each orifice

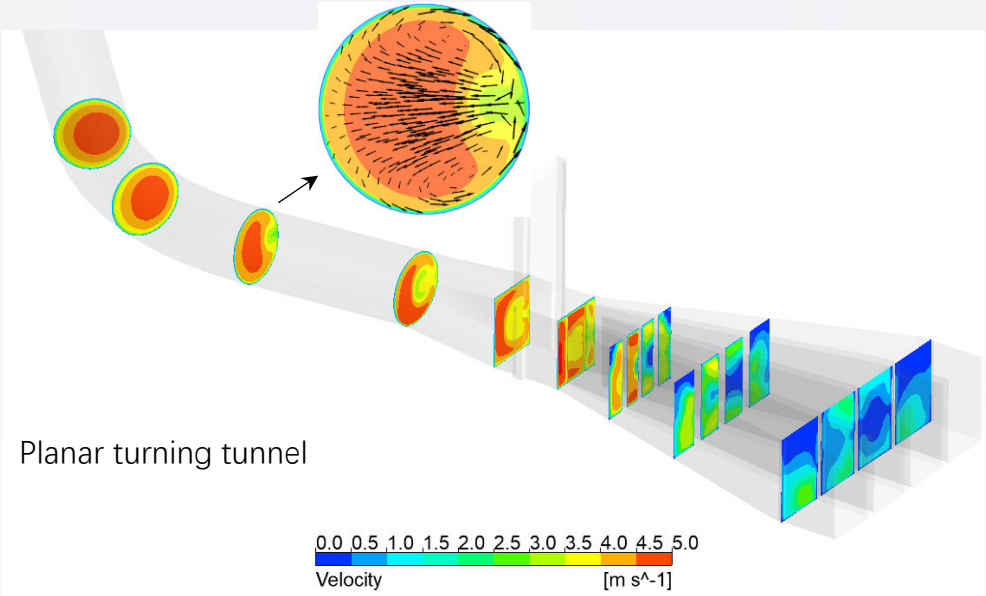
L	O-1	O-2	O-3	O-4	Deviation Ratio
2.5D	27.87	31.40	18.74	21.99	12.66
+∞ (straight)	23.25	26.75	26.50	23.50	3.49

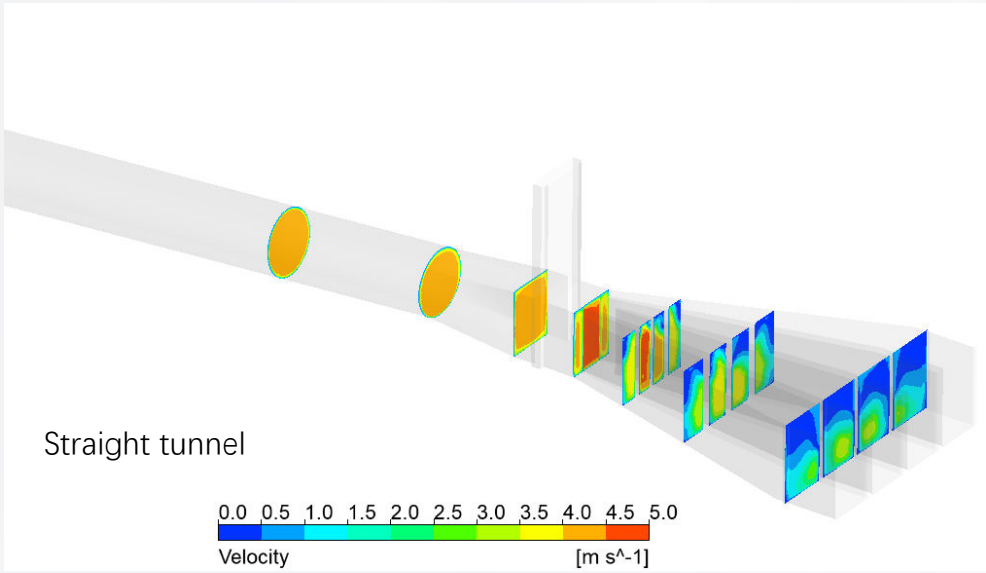
- The non-uniformity of the flow velocity distribution at the trash rack

L	O-1	O-2	O-3	O-4
2.5D	2.88	2.06	1.92	2.68
+∞ (straight)	3.54	2.98	2.96	3.54



◆ Uneven flow distribution at each orifice
◆ Lower non-uniformity of flow velocity distribution



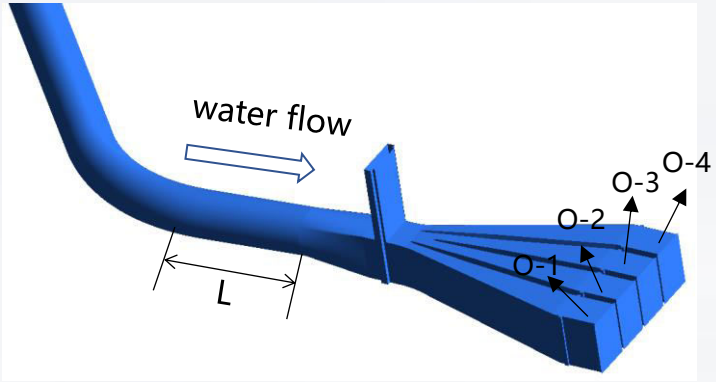


Results

➢ The effect of **straight section length** (L) downstream of the turning section

- Flow distribution ratio of each orifice

L	O-1	O-2	O-3	O-4	Deviation Ratio
2.5D	27.87	31.40	18.74	21.99	12.66
5.6D	25.21	23.57	30.10	21.11	8.99
8.0D	24.29	30.56	23.32	21.83	8.74



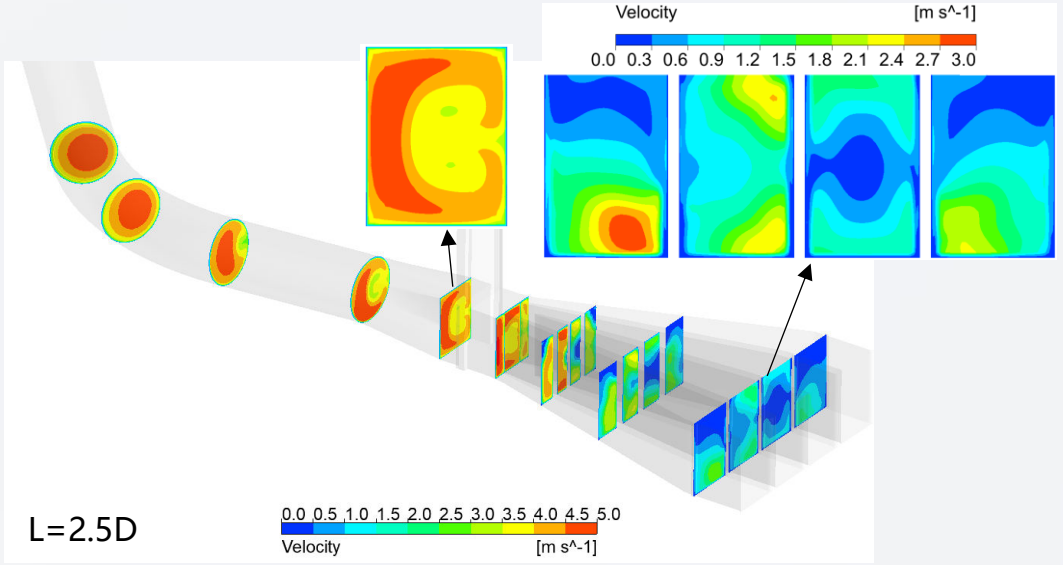
- The non-uniformity of the flow velocity distribution at the trash rack section

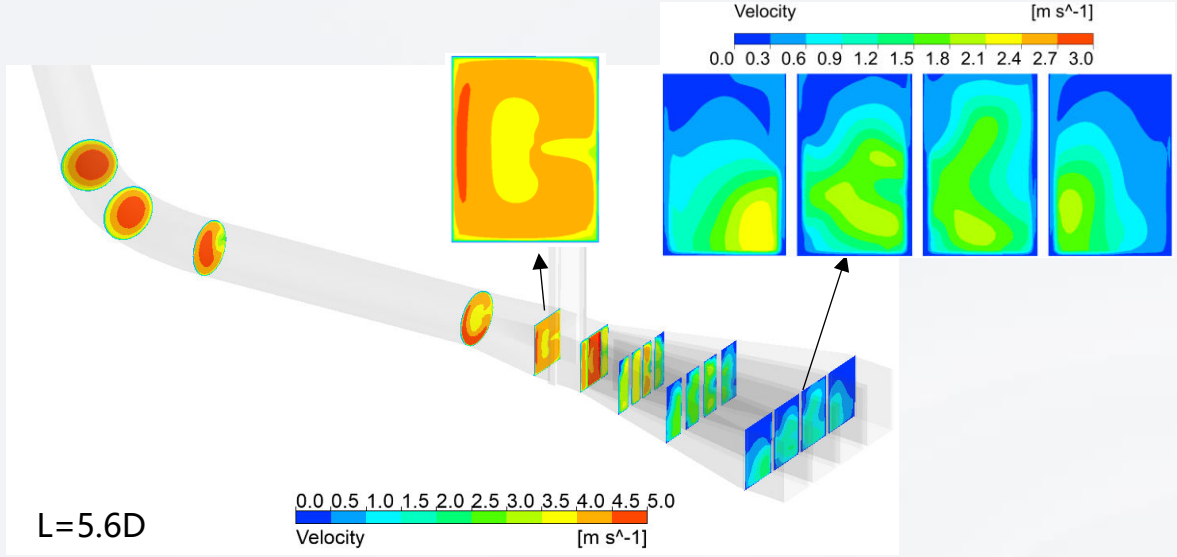
L	O-1	O-2	O-3	O-4
2.5D	2.88	2.06	1.92	2.68
5.6D	2.67	2.3	1.94	2.45
8.0D	3.22	2.55	2.89	3.39

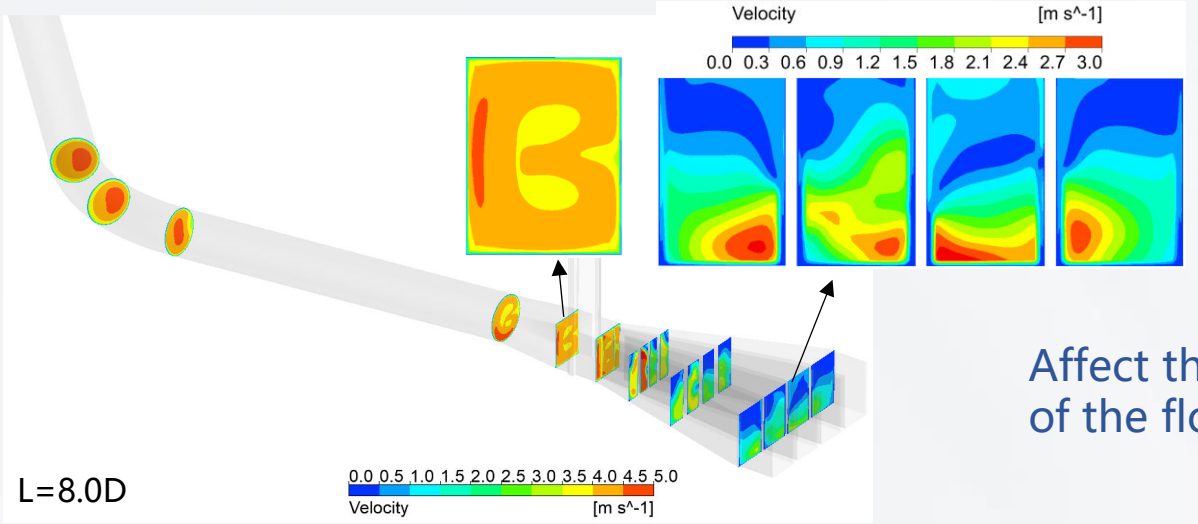
- The longer the straight section, the more uniform the flow distribution ratio of each orifice
- The longer the straight section, the non-uniformity of the flow velocity distribution at the trash rack section may not necessarily improve

Results

- The effect of **straight section length** (L) downstream of the turning section







More sufficient adjustment of the circulation

Affect the vertical distribution of the flow velocity

Results

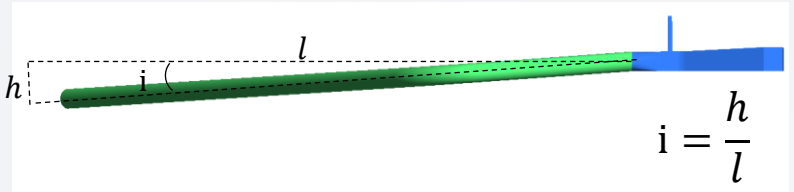
➢ Influence of **Tunnel Slope**

- Flow distribution ratio of each orifice

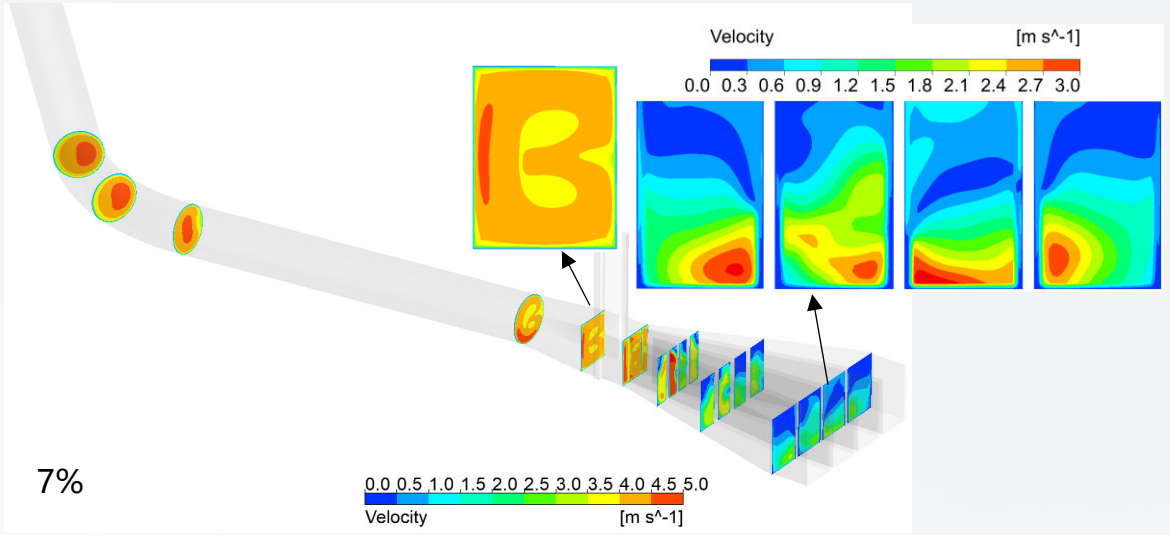
i	O-1	O-2	O-3	O-4	Deiation Ratio
7%	24.29	30.56	23.32	21.83	8.74
8%	24.48	30.38	23.72	21.41	8.97

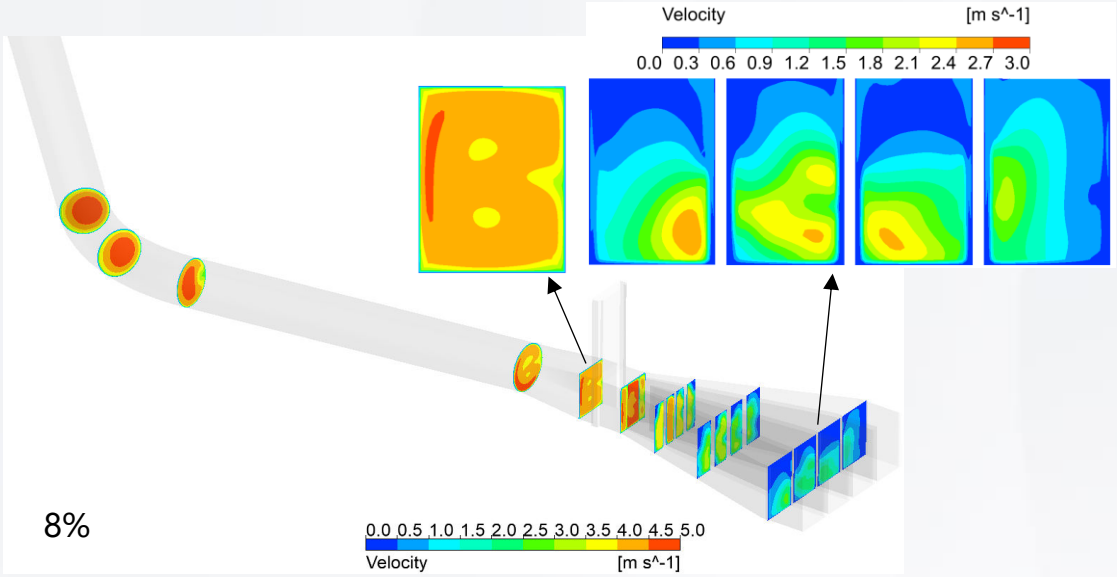
- the non-uniformity of the flow velocity distribution at the trash rack

i	O-1	O-2	O-3	O-4
7%	3.22	2.55	2.89	3.39
8%	2.98	2.19	2.62	2.55



The larger the slope, the more uniform the flow velocity distribution on the cross-section of the trash rack.





➢ Influence of **the location of the slope change**

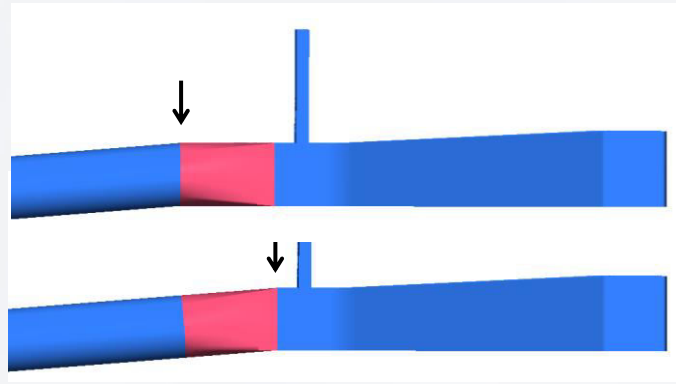
- Flow distribution ratio of each orifice

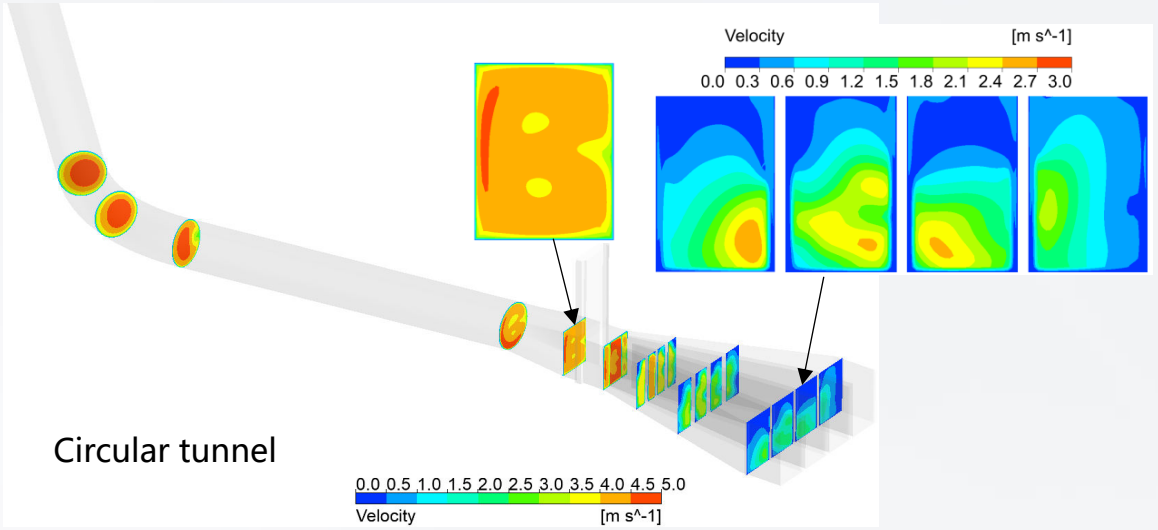
Changing position	O-1	O-2	O-3	O-4	Deviation Ratio
Circular tunnel	24.48	30.38	23.72	21.41	8.97
transition section	24.31	29.32	25.14	21.23	8.09

- the non-uniformity of the flow velocity distribution at the trash rack

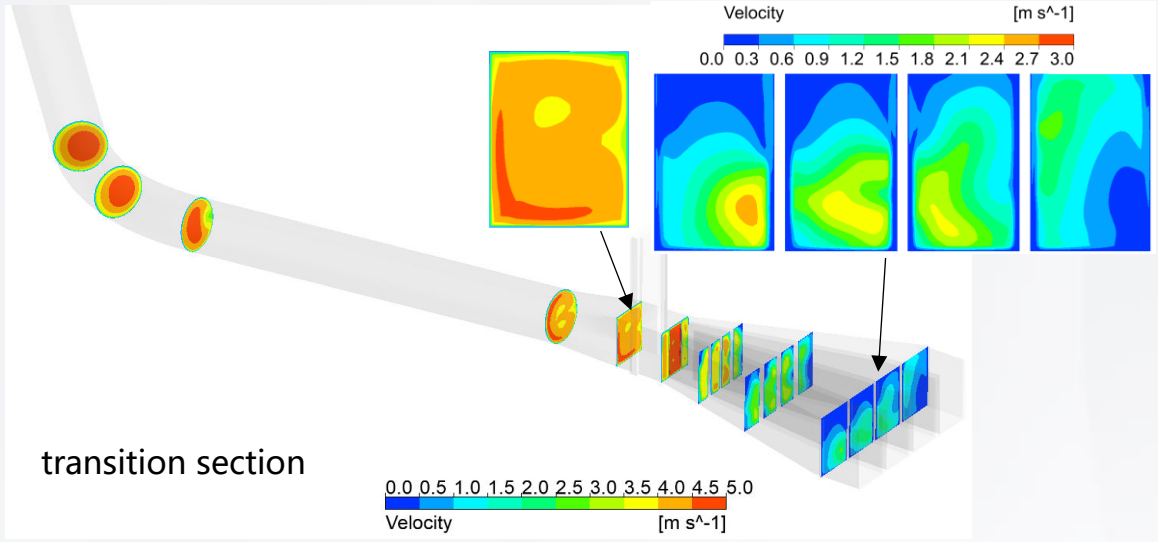
Changing position	O-1	O-2	O-3	O-4
Circular tunnel	2.98	2.19	2.62	2.55
transition section	2.90	2.22	2.43	2.14

Better





Circular tunnel



transition section

Conclusions

- The **longer** the straight section, the **more uniform the fow distribution ratio** of each orifice. However, the **non-uniformity of flow velocity** at trash rack section **may not necessarily improve**.
- A **larger** the tunnel slope or a **longer** the transition section can lead to a **more uniform** distribution of the flow velocity at trash rack section.
- To adopt **a suitable slope changing position** can **improve both** the fow distribution ratio of each orifice and the non-uniformity of flow velocity distribution at trash rack section.

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Thank you!

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Humans and Nature

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