

Numerical Study of a Turbulent Hydraulic Jump

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Objective

Our ultimate goal is to study the breaking waves.

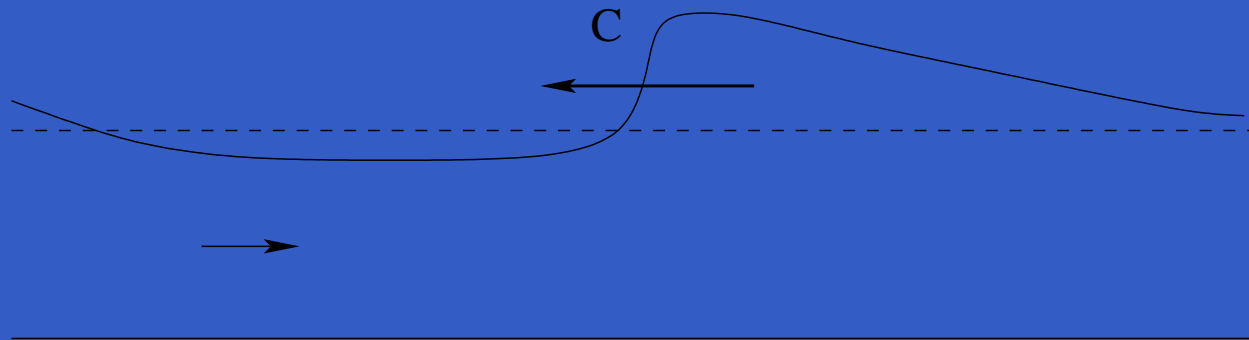
A moving bore



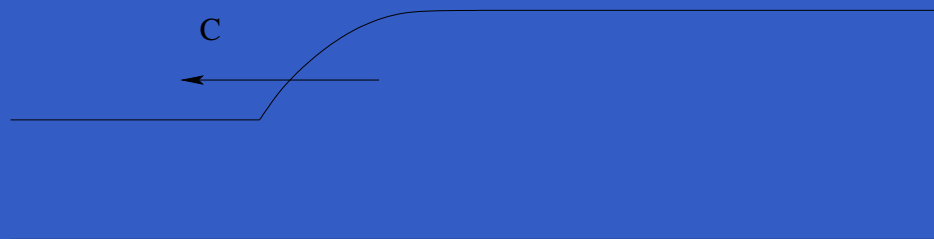
Qiantang Bore China (Courtesy of Dr J. Eric JONES).

It is about 8 to 9 meters at its highest and moves at about 30km/h.

From breaking wave to bore to hydraulic jump



A breaking wave on the beach

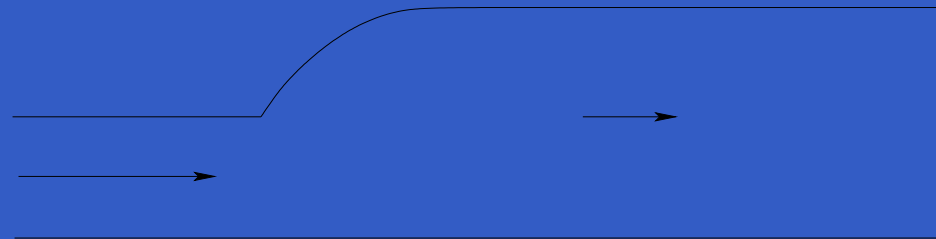


A bore moving in speed C .

From breaking wave to bore to hydraulic jump



A bore moving in speed C .



A hydraulic jump.

Previous Studies

Experimental studies

- Mostly focus on high Froude number flow;
- Data resources for weak hydraulic jump are limited ;

Theoretical and Numerical studies

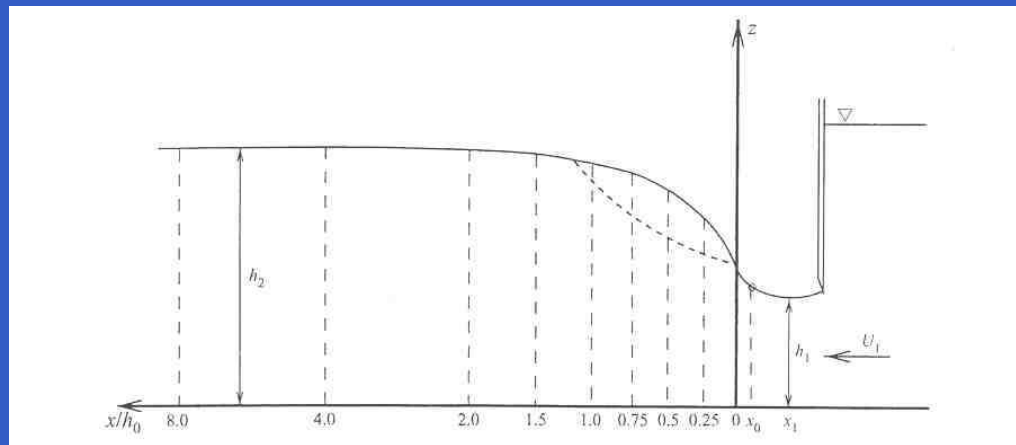
- Based on nonlinear shallow water equations;
- Approximate the bore/hydraulic jump as discontinuity of water, i.e., "shock";
- Assume hydraulic static pressure.

Present Numerical Model

To model the hydraulic jump, we use

- Reynolds-averaged momentum equations (RANS);
- $k - \epsilon$ model with "wall function";
- VOF method to describe the free surface;
- Model results are compared with lab measurements;

Lab Experiment of Bakunin (1995)

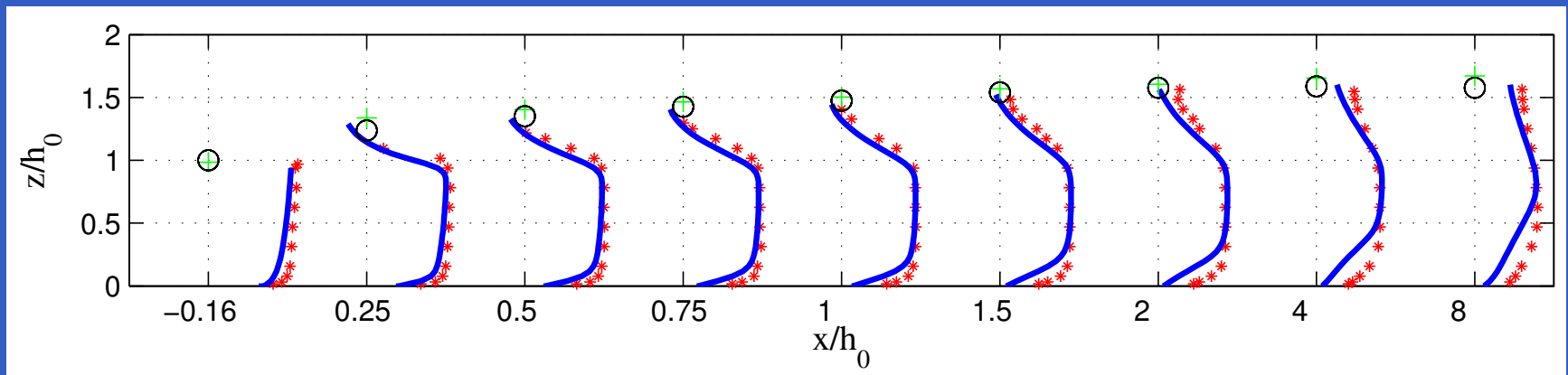


Sketch of experimental setup and definition of parameters (after Svendsen *et al.* 2000)

Jump No.	Froude No.	h_0 (m)	U_0 (m/s)
1	1.38	0.072	0.9483
2	1.46	0.064	1.0597
3	1.50	0.059	1.1621

Model Results-Mean velocity

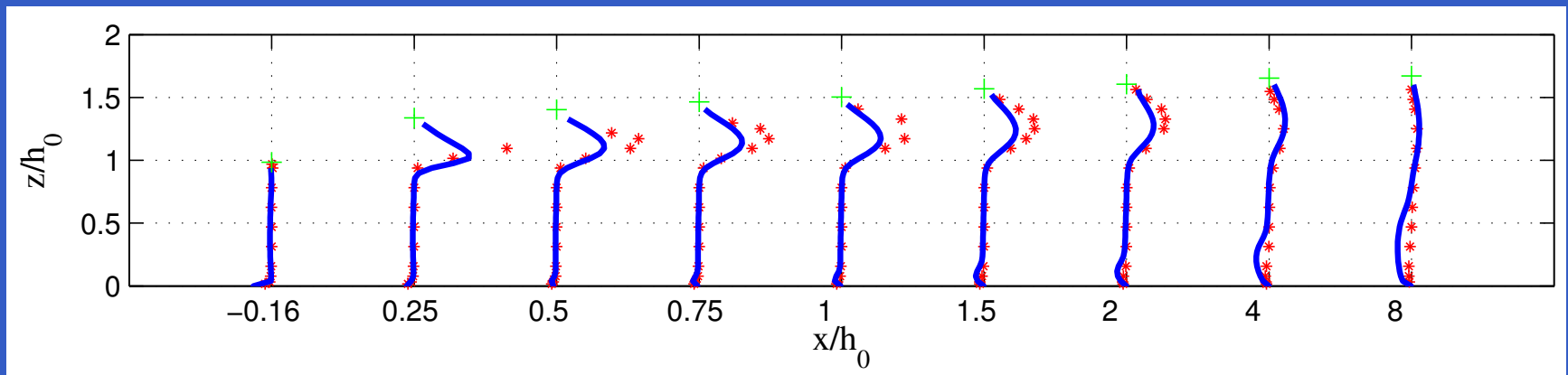
Jump 2: Froude No. 1.46



Free surface elevation and mean horizontal velocities. *: measured mean velocities; -: modeled mean velocities; +: measured surface elevations; O: modeled surface elevation. Data are from Bakunin (1995) and Svendsen *et al.* (2000).

Model Results: Reynolds stresses

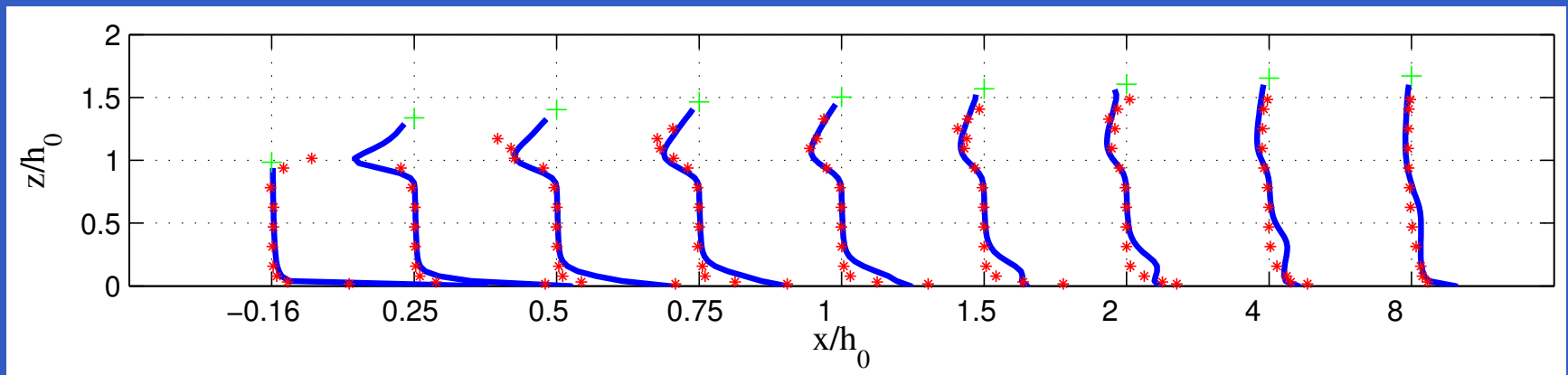
Jump 2: Froude No. 1.46



Mean Reynolds stresses $\overline{u'w'}$. *: data; -: model results; +: measured surface elevations. Data are from Bakunin (1995) and Svendsen *et al.* (2000).

Model Results: mean vorticity

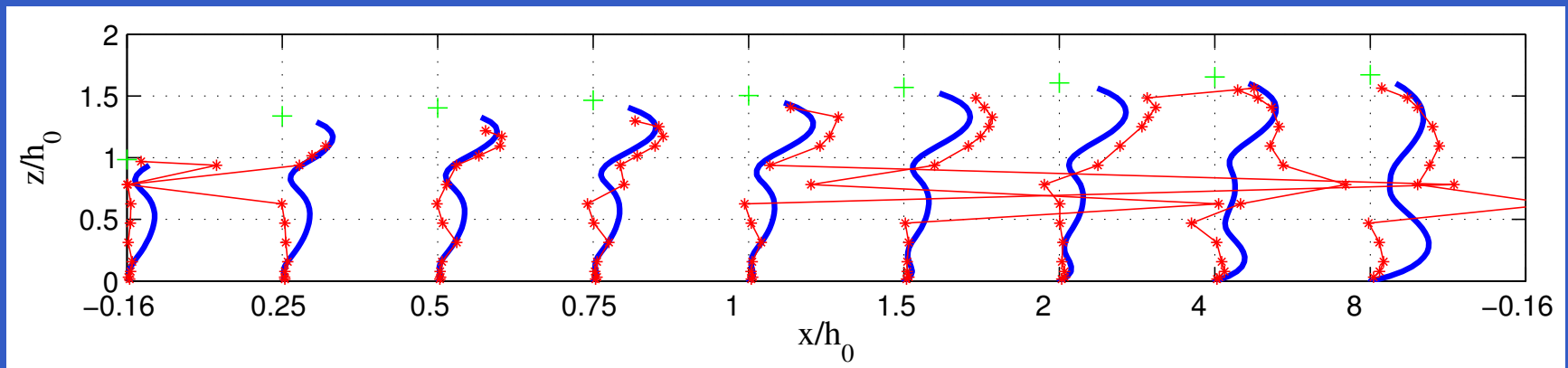
Jump 2: Froude No. 1.46



Mean vorticity $\omega \approx \frac{\partial U}{\partial z}$. *: mean vorticity from measured mean velocities; -: mean vorticity from modeled mean velocities; + : measured surface elevations. Data are from Bakunin (1995) and Svendsen *et al.* (2000).

Model Results: eddy viscosity

Jump 2: Froude No. 1.46



Eddy viscosity ν_t . *: data; -: model results. Data are from Bakunin (1995) and Svendsen

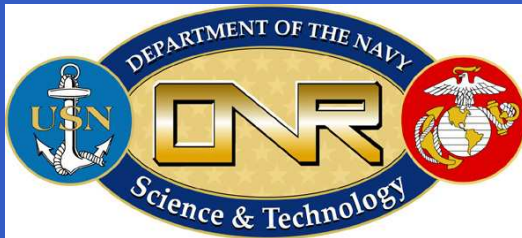
et al. (2000). ν_t is approximated by $-\overline{u'w'}/\frac{\partial U}{\partial z}$.

Summary and Conclusions

- A numerical model based on RANS equations are applied to study the hydraulic jump.
- Model results agree well with data in terms of free surface and mean horizontal velocities, but underestimate Reynolds stress.
- Some interesting features of the flow can be obtained, but further improvements of the numerical model is needed.

Thank you!

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