Conference Paper, Published Version

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Turbulence Intensity Distribution in Flow Field under High Head Slid Gates in Conditions of Operating Two Gates

TURBULENCE INTENSITY OF HIGH HEAD SLID GATES IN CONDITIONS OF OPERATING TWO GATES

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ABSTRACT

This research intends to investigate influence of opening two gates simultaneously on the turbulence intensity distributions around high head lift gate. The turbulence Intensity was obtained from a two-dimensional Laser Doppler Velocimeter(Laser Doppler Anemometer). Thus the investigation was applied by an experimental hydraulic model built and taken place in Michelle Hydraulics Laboratory in civil engineering department at The University of Melbourne. Finally the research results how turbulence Intensities are distributed over the flow field.

Keywords: turbulence intensity, high head gate, Laser Doppler Velocimeter, hydraulic model, hydraulic structures

1. INTRODUCTION

In the high dams controlling the flow in bottom outlets plays an important role. Practically there are two high head gates in bottom outlet conduit of dams, the first one is service gate for controlling the flow and the second gate (before service gate) is emergency gate for maintaining and repairing service gate. Depending on the condition, the flow is controlled by gates or valves. Among various types of control structures, lift gates are widely used at high head bottom outlets. The leaf gates can operate either in a gate chamber or in an intake structure. Therefore, existing high velocity and turbulence around the gates will cause damages in this structure such as cavitation, vibration and excessive hydrodynamic forces.

By knowing turbulent Intensities distributions around the gates, we can predict in where Laminar, turbulence or super turbulence behaviors take place. This helps to designers and who use the numerical model in these kinds of structures.

For measuring turbulence parameters, LDV (Laser Doppler velocimeter) is a main and useful instrument. The LDV is needed for measuring temporary velocity required in determining turbulence intensities, turbulent stress, mean velocity and etc. In this research, LDV(LDA) was used to measure turbulence parameters.

2. THEORITICAL REVIEW

The structures such as bottom outlet gates, the turbulence intensity in the longitudinal direction is an important factor for vibration, cavitation, pressure fluctuation, sediment motion and etc.

The longitudinal turbulence intensity, also often referred to as turbulence level, is defined as:

$$I = q' / q \qquad (1)$$

Where q' is the root-mean-square of the turbulent velocity fluctuation in the longitudinal direction and q is the mean velocity (Reynolds averaged). Two-

dimensional components of q' are u' and v'.
q' can be computed as:

$$q' = [\ (u'^2 + v'^2) / 2]^{0.5} \tag{2}$$

Also, in two-dimensional conditions, q can be computed from the two mean velocity components e.g. u and v:

$$q \equiv [\ u^2 + v^2]^{\ 0.5} \tag{3}$$

In this research the flow has been studied in two dimensional conditions, so it is considered in two components of x and y. The $-\rho.u'v'$ is the turbulence (Reynolds) stress that presents the effect of turbulent.

According to some researcher, if Turbulence Intensities become less than 5% there is the laminar flow and more than 10% there is the turbulence flow. Also according to a category there are four cases of turbulence flow as:

1. Super-turbulence case: the turbulence intensity is more than 20%.
2. High-turbulence case: the turbulence intensity is between 5% to 20%.
3. Medium-turbulence case: the turbulence intensity is between 1% and 5% .
4. low-turbulence case: the turbulence intensity is very low and below 1%.

3. EXPERIMENTAL MODEL AND MEASURING

For providing experimental data we need to build a model and measure the flow by LDA.

The dimensions of model are presented in two sketches (figures 1 and 2). The model dimensions have been designed according to location, facilities and hydraulic limitations. The model was made of Plexiglas material because of lower roughness and more clear while visiting flow. The model after designing was built in the workshop of Civil Engineering Department and then it was set up in Michelle Hydraulics Laboratory of the Department. For the safety against dangerous laser beams, the whole of the model was taken in a cover room built of metal plates with black color inside. In this cover room, beams can’t exit out directly.

According to the figures 1 and 2, the model has built of two gates, the first gate is emergency gate and the other gate is service gate.

The flow in the system is circulated from underground reservoir to that same reservoir again. The route of flow is underground reservoir, suspension reservoir, model, underground reservoir.

The measurable point coordinates are recognizable according to Figure 3 so that the measurable points are made by crossing the dashed lines. The laser probe is moved by X-Y mover on the coordinates. According to this Figure ι is a horizontal distance from first gate back to desirable measurement point. If ι becomes negative ($\iota<0$), the point will be before the first gate region. In this region the directions of measurement are taken on ι= -360,-240, -120, -60, -10 mm (or respectively ι/H = -2.4, -1.6, -0.8, -0.4, -0.07). If ι becomes positive, the point will happen after first gate region, so that in between two gates, 25mm $\leq \iota \leq$ 97.5mm or $0.17 \leq \iota/H \leq 0.65$, the measurement directions are taken on ι= 25, 65, 97.5mm (or respectively ι/H = 0.17, 0.43, 0.65) and after second gate, ι > 97.5mm or $\iota/H > 0.65$, the measurement directions are taken on ι= 130, 180mm (or respectively ι/H = 0.87, 0.12). The points taken on ι/H = 0.17 and 0.65 are, respectively, under first gate and second gate.

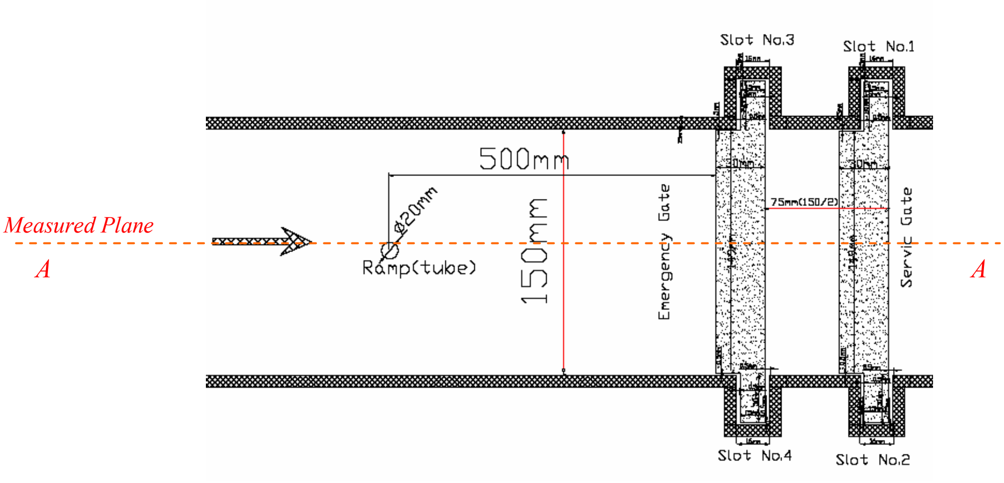

Figure 1 plan of the model Geometry (the measured plane is showed as dashed line of A-A)

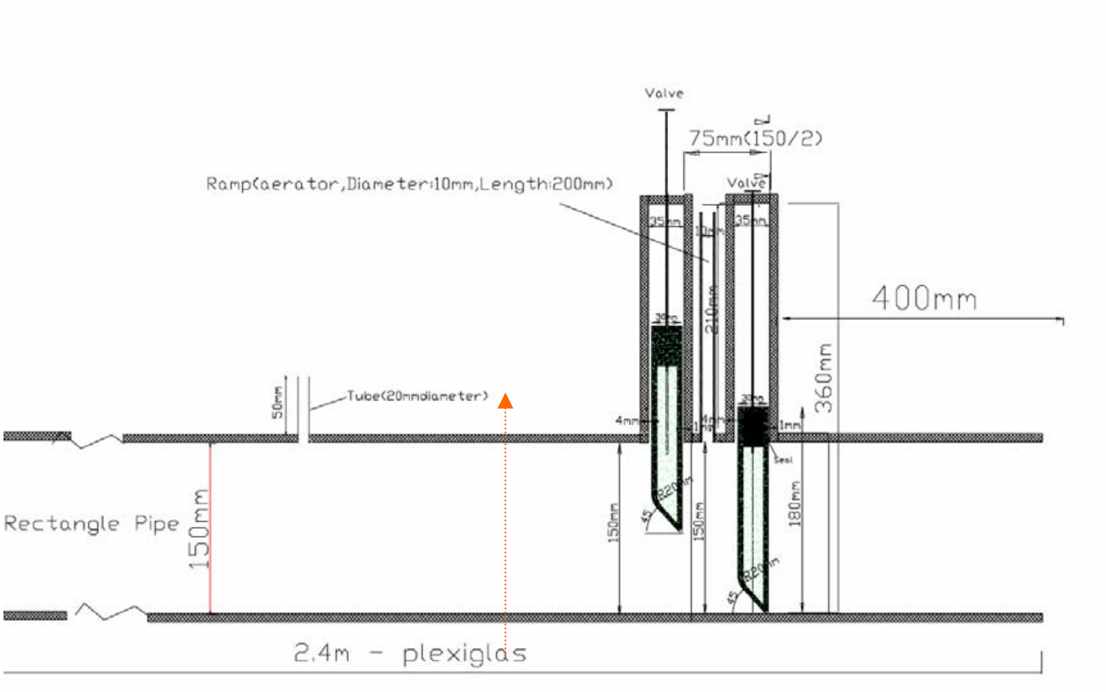

Figure2 Section of A-A showed the model geometry in the middle Perspective.

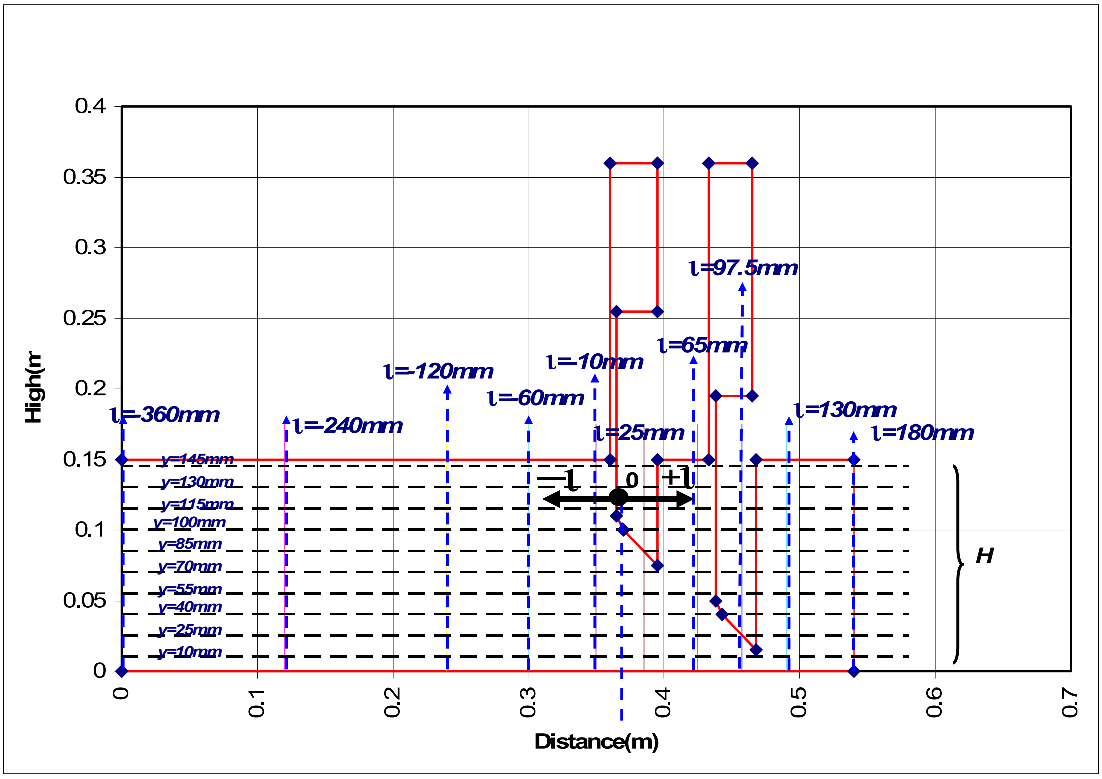

Figure 3 Measurable points coordinates by LDV

The measurements are played on the various points and in various conditions of opening gates. There are 7 positions for opening gates consisted of 30%-10%, 70%-10%, 30%-30%, 50%-30%, 70%-30%, 50%-50% and 70%-50%. In this format (m%-n%) the first number is related to Opening upstream gate(first gate or Emergency gate) and second one is related to downstream gate(second gate or service gate) in percent.

The experiment stages for measuring were done with respect to various opening gates (10%, 30%, 50%, 70%). Also there is a constant head behind the first gate (about 3.5m) and flow rate is various (maximum to 0.4 m^3/s). The model section size is 150×150(mm×mm). In these conditions, the turbulent flow is considerable. The model occupies 8m length and 3m width with proper drainages.

4. ANALYSIS

Longitudinal turbulence intensity (**I**) distributions have been showed in graphs of Figure 4. Also table 1 show the averages of turbulence intensities in different regions of flow with various gates positions. The graphs and the table are interpreted as bellow:

a) If m>n (the first gate is more opened than second gate e.g. h1>h2) gates positions make three flow regions; region a.1 is before first gate ($\iota/H < 0$), region a.2 is between two gates ($0 < \iota/H \leq 0.65$) and region a.3 is after second gate ($\iota/H > 0.65$).

Region a.1: Here, the turbulence intensity distribution is more in uniform and less in amounts than next region (region a.2). However around the corner of upper in just behind of gate (around $y/H \approx 0.95$ and $\iota/H \approx -0.07$) for Turbulence intensity, we have an unexpected and sharp increase because of existing of intensive eddies. The average of **I** over the region a.1 is 17.1%.

Region a.2: here the entire volume of between two gates is completely occupied with water flow. Because of complex geometry boundary in between two gates, separating the flow and sudden expansion and contraction, we expect a high turbulence there. Generally, according to the graphs, the turbulence intensities profiles are both higher in amount and more non uniform than other regions ones (region a.1 and a.2). In this region **I** reaches in maximum in ι/H ≈ 0.43 and 0.6< y/H<0.95 because there are big eddies. The average of **I** in this the region is 76.7%.

Region a.3: After second gate, flow is high speed and become as a free jet. Here turbulence intensities distribution becomes more uniform and less amount than second region but the amounts not more than the region a.1. The average of **I** in this region is 48.9% .

b) If m ≤ n (the first gate is same or less opened than second gate, meaning h1≤ h2), therefore, the volume of between two gates is not full of water so the flow after first gate is applied as free jet flow (similar to the region a.3). Actually when we have m ≤ n there is just one gate, meaning the first gate, affected on flow. Therefore gates positions make two flow regions; the first one is before first gate meaning ι/H < 0 and second one is after first gate meaning 0 < ι/H. In general when m=n (based of table 1) the averages of **I** in all regions meaning 26.2% for 30%-30% and 29% for 50%-50% are lower than others.

Region b.1: In this region the distributions of I are applied similar to previous first region (m>n). The turbulence intensity distribution is less in amounts than region b.2. However around the upper in just behind of first gate (y/H≈ 0.95 and ι/H ≈ -0.07), for turbulence intensity, because of existing of eddies, we have an unexpected and sharp increase (special in position of 50%-50%). The average of I over the region b.1 is 20.7%.

Region b.2: In this region the distributions of Turbulence intensity are applied similar to a.3. Although the average of turbulence intensities in this region is more than region b.1 (m ≤ n), it is less than the average of the turbulence intensities in region a.3 in condition of m>n. The average of **I** is 34.5%.

Generally, on the average, the maximum **I** that is 149.3% is referred to region between two gate (0 < ι/H < 0.65) and for m>n, meaning region a.2 for gate position of 50%-30%. Also the minimum one that is 11.4% is referred to region of before first gate (ι/H < 0) and for m>n meaning region a.1 for gate position of 30%-10%. The special areas where **I** is high are in upper of between two gates region (e.g. 0.17 < ι/H < 0.65 and 0.6< y/H<0.95) and upper of just behind the first gate (y/H≈ 0.95 and ι/H ≈ -0.07).

Also for recognizing the distribution of **I** around the gates, visually figures 5 to 11 have been presented counters of **I**. According to the figures, generally there is high and maximum turbulence intensity between two gates.

5. CONCLUSIONS

In comparison of mean velocity (q) with Turbulence Intensity (**I**), the distributions of q and **I** over flow fields show the factor of the high speed flow is not always the cause of the high turbulence, because in a low speed flow, a boundary with complex geometry can make a considerable turbulence. Therefore, there are placements in where velocity is low, but because of existence of eddies, the turbulence is high. In the experimental model in between two gates and above the lip gate (about 0.17< ι/H <0.65 and 0.6< y/H<0.95, depended on gates position), also around the corner and upper and just behind of gate (y/H≈ 0.95 and ι/H ≈ -0.07), the

Turbulence Intensity is high but mean velocity is low. In base of the turbulence intensity distributions, the maximum **I** (on the average 149.3%) is referred to region between two gates (0.17 < ι/H < 0.65) with gate position of 50%-30% for m>n. Also the minimum one (on the average 11.4%) is referred to region in before first gate (ι/H < -0.07) with gate position of 30%-10% for m>n. The others placements in where **I** is high, are in upper of gates lips between two gates region (-0.07 < ι/H < 0.65 and 0.6< y/H<0.95), also in upper and just behind the first gate (e.g. y/H≈ 0.95 and ι/H ≈ -0.07).

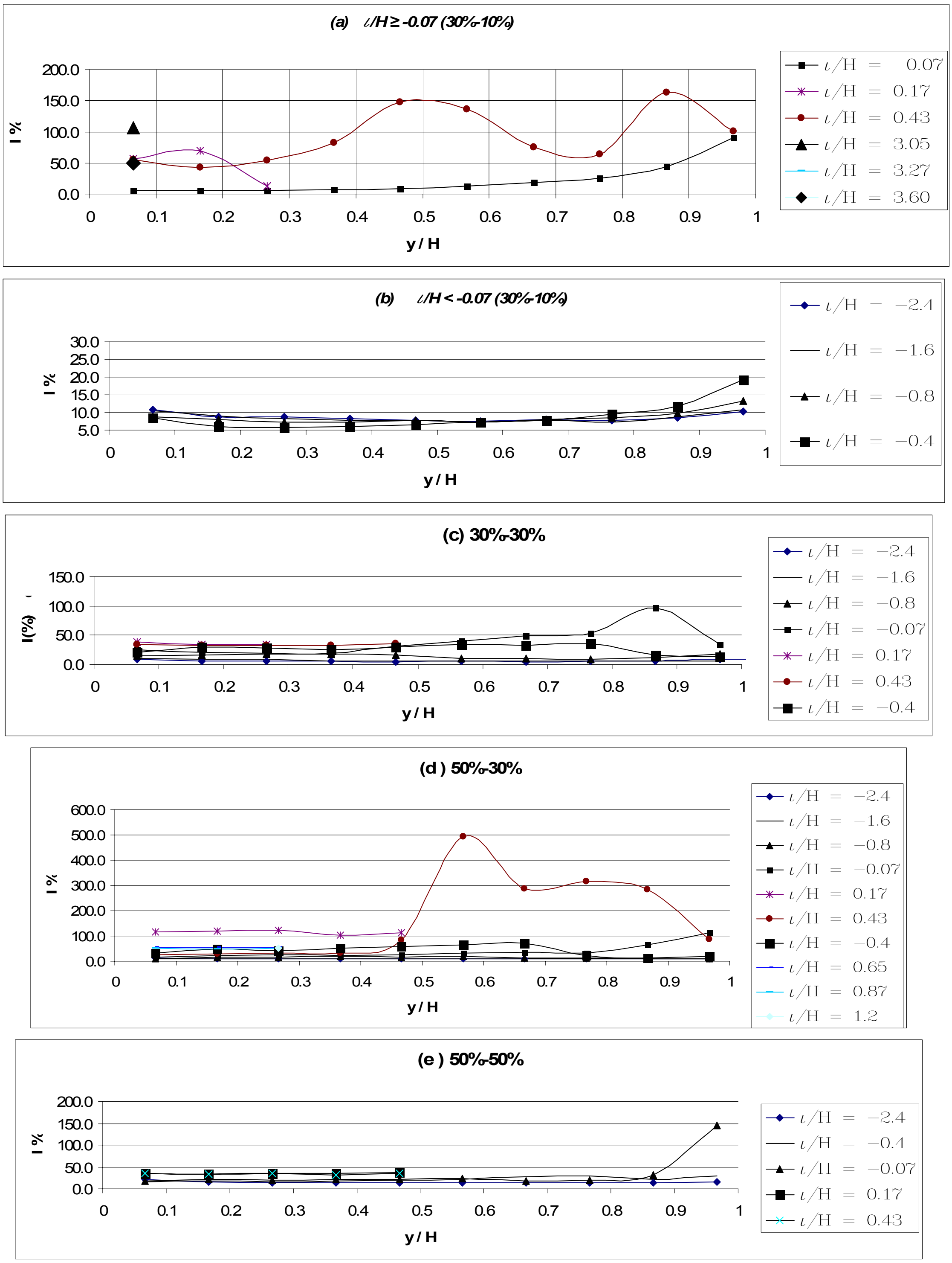

Figure 4 Distribution of Turbulence Intensity with respect to gates position

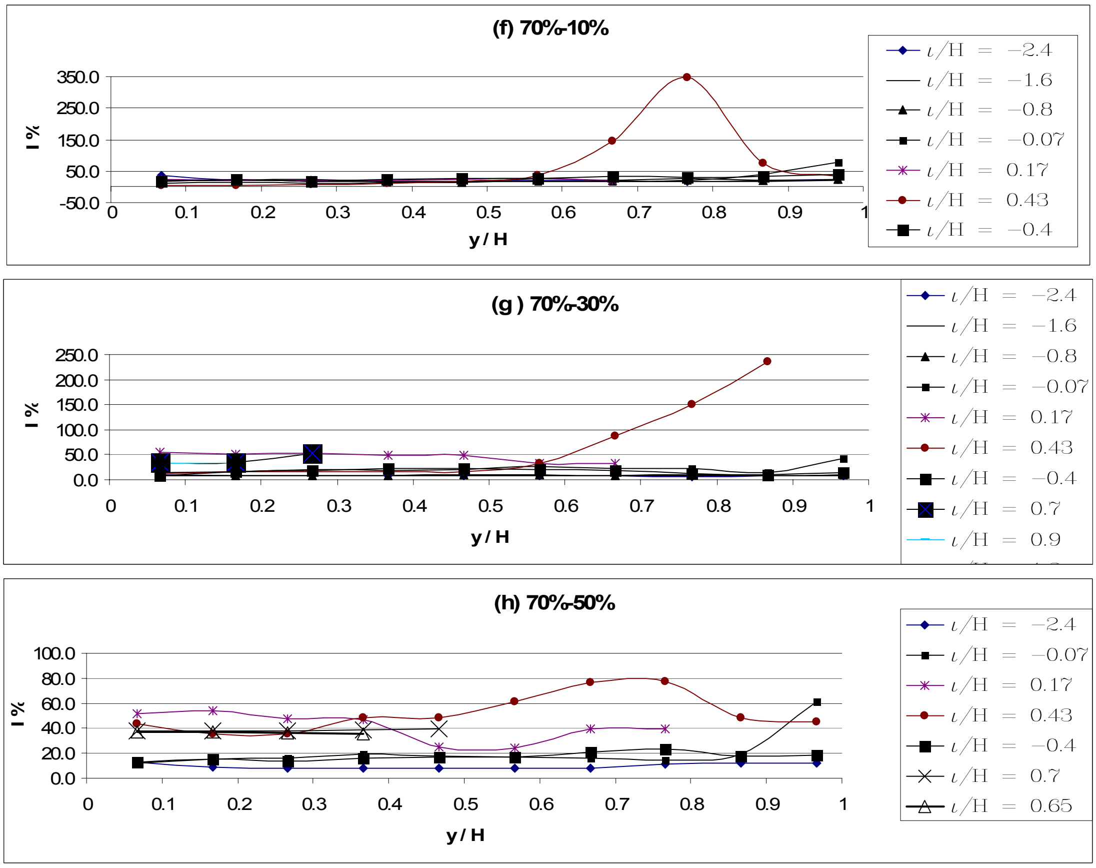

Figure 4 Distribution of Turbulence Intensity with respect to gates position

Table 1 Averages of Turbulence Intensity in each region.

flow region		Gates position							
		30%-10%	30%-30%	50%-30%	50%-50%	70%-10%	70%-30%	70%-50%	Average
m>n	before gate 1 $\iota/H < -0.07$	8.6	-	19.1	-	22.1	10.3	13.5	14.7
	between two gates $-0.07 < \iota/H < 0.65$	81.4	-	105.2	-	39.8	43.2	37.8	61.5
	after gate 2 $\iota/H > 0.65$	68.9	-	52.3	-	non	36.9	37.6	48.9
m=n	before gate 1 $\iota/H < -0.07$	-	13.0	-	18.1	-	-	-	15.6
	after gate 1 $\iota/H > -0.07$	-	36.1	-	34.3	-	-	-	35.2
	Average	53.0	24.6	58.9	26.2	30.9	30.1	29.7	35.2

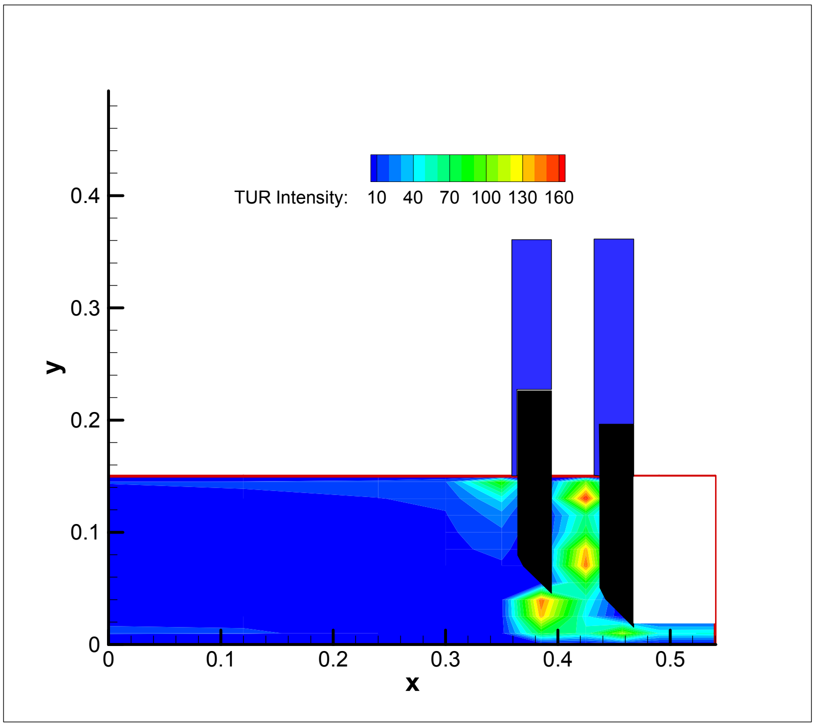

Figure 5 Turbulence Intensity contours around the gate for opening 30%-10% (All are as meter and Turbulence intensity is as Percent).

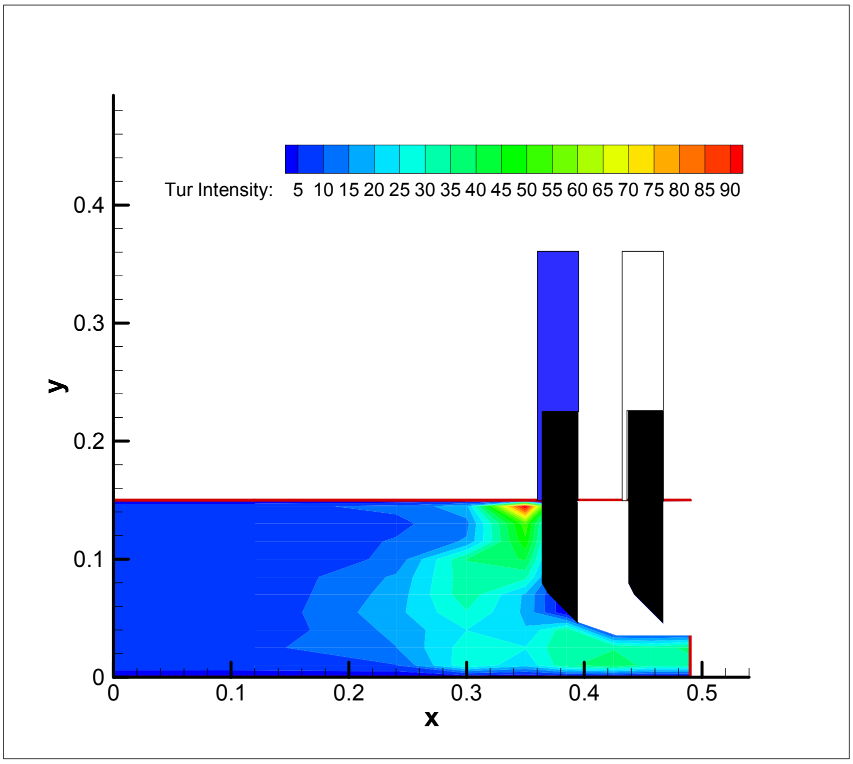

Figure 6 Turbulence Intensity contours around the gate for opening 30%-30% (All are as meter and Turbulence intensity is as Percent).

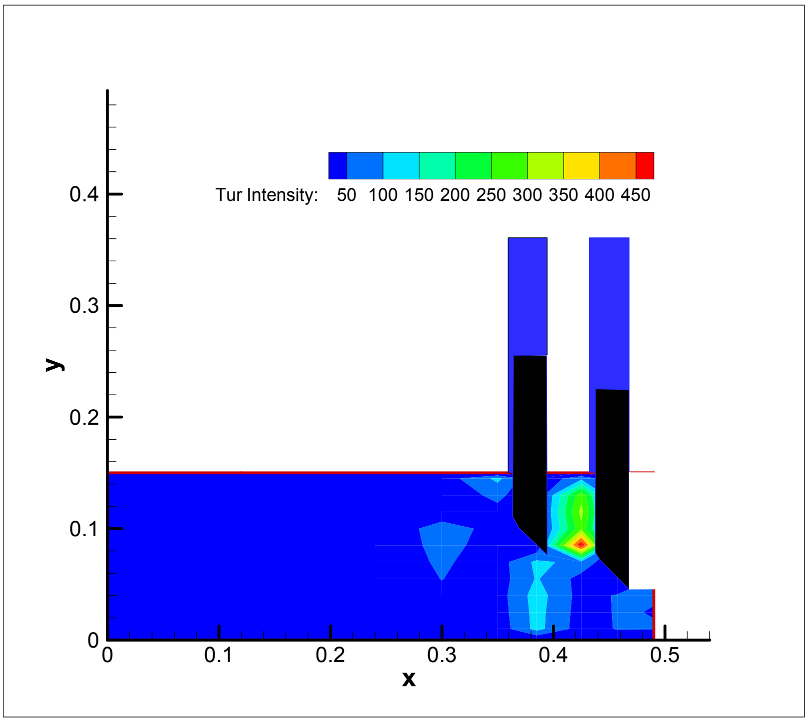

Figure 7 Turbulence Intensity contours around the gate for opening 50%-30% (All are as meter and Turbulence intensity is as Percent).

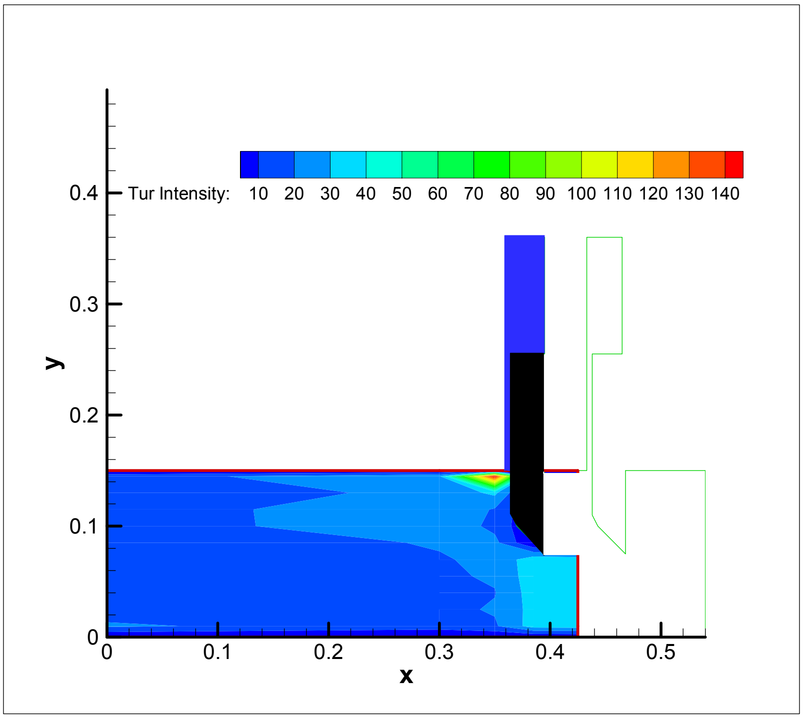

Figure 8 Turbulence Intensity contours around the gate for opening 50%-50% (All are as meter and Turbulence intensity is as Percent).

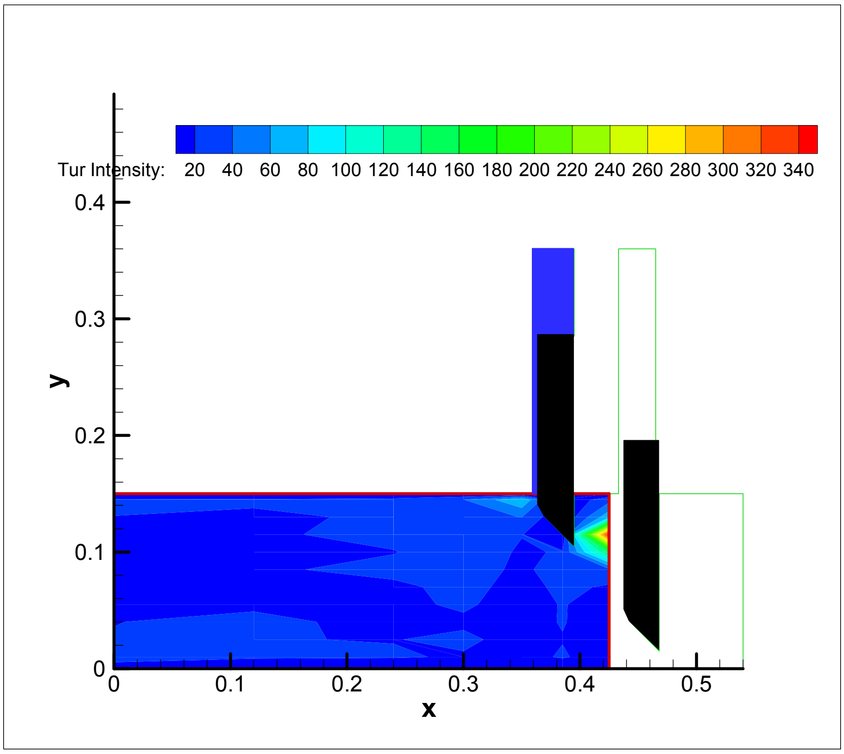

Figure 9 Turbulence Intensity contours around the gate for opening 70%-10% (All are as meter and Turbulence intensity is as Percent).

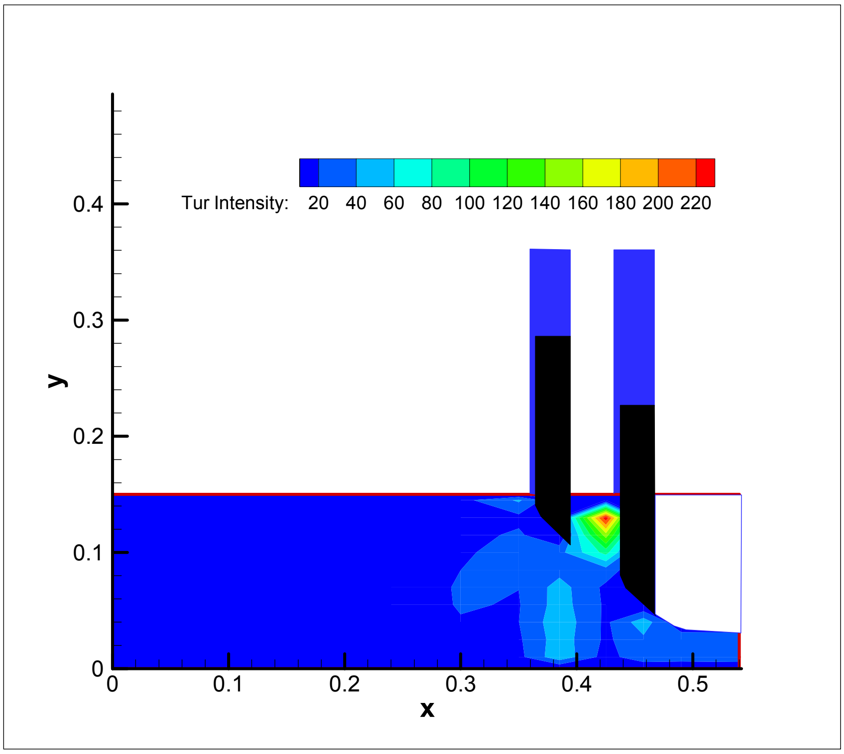

Figure 10 Turbulence Intensity contours around the gate for opening 70%-30% (All are as meter and Turbulence intensity is as Percent).

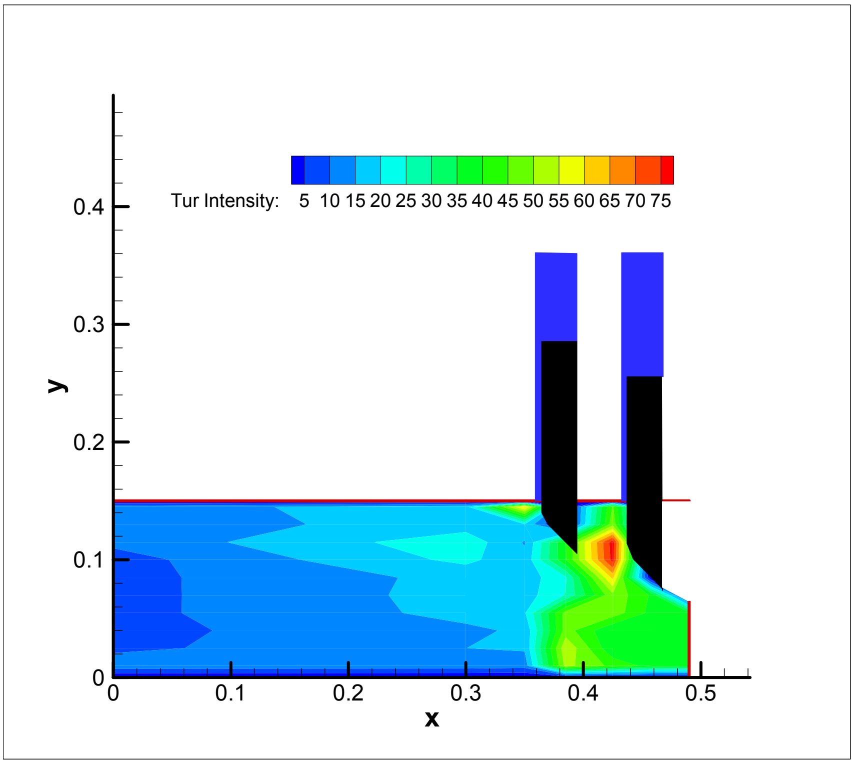

Figure 11 Turbulence Intensity contours around the gate for opening 70%-50% (All are as meter and Turbulence intensity is as Percent).

ACKNOWLEDGMENTS

The writer thanks Association Professor Roger Huge as my supervisor in the university, Dr. George Assaad and Professor John D. Fenton for their scientific assistance and Youshka shepherd, Tim Berrigan for their technical assistance.

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