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ASSESSMENT OF ENERGY LOSSES IN NARROWING CHANNELS UNDER CONDITIONS OF UNSTEADY FLOW

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ОЦЕНКА ПОТЕРЬ ЭНЕРГИИ В УЗКИХ КАНАЛАХ В УСЛОВИЯХ НЕСТАБИЛЬНОГО ПОТОКА

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ABSTRACT

This paper presents an improved hydraulic model for analyzing unsteady flow behavior in variable cross-section open channels, with particular focus on converging rectangular inlet chambers. The study aims to enhance the accuracy of hydraulic computation under non-stationary conditions by incorporating the influence of vortex structures and gradual contraction geometry. Experimental investigations were carried out using a laboratory model with a converging rectangular channel of 120 cm length, 80 cm inlet width, and outlet widths of 40, 35, 30, and 25 cm. Average flow velocity was maintained near 0.67 cm/s, and four discharge rates of 30, 25, 20, and 15 m^3/h were analyzed. Flow velocities were measured using a micro-propeller current meter. The results showed that increasing flow discharge and shortening contraction length both intensify vortex formation. The proposed model improves flow prediction accuracy by up to 8% compared with classical steady-state approaches and provides recommendations for optimizing inlet chamber geometries in open-channel systems.

АННОТАЦИЯ

В данной работе представлена усовершенствованная гидравлическая модель анализа неустановившегося поведения течения в открытых каналах с переменным поперечным сечением, с особым акцентом на сходящиеся прямоугольные входные камеры. Исследование направлено на повышение точности гидравлических расчетов в нестационарных условиях за счет включения влияния вихревых структур и геометрии постепенного сжатия. Экспериментальные исследования проводились с использованием лабораторной модели сходящегося прямоугольного канала длиной 120 см, шириной входа 80 см и шириной выхода 40, 35, 30 и 25 см. Средняя скорость потока поддерживалась близко к 0,67 см/с, и были проанализированы четыре скорости стока 30, 25, 20 и $15m^3/h$. Скорости потока измерялись с помощью микро вертушка. Результаты показали, что увеличение расхода потока и уменьшение длины сжатия усиливают образование вихря. Предлагаемая модель улучшает точность прогнозирования потока до 8% по сравнению с классическими стационарными подходами и дает рекомендации по оптимизации геометрии входной камеры в открытых каналах.

Keywords: hydraulic modeling, unsteady flow, variable cross-section channel, vortex field, flow contraction, open channel hydraulics.

Ключевые слова: гидравлическое моделирование, неустановившийся поток, канал переменного сечения, вихревое поле, сжатие потока, гидравлика открытого канала.

Introduction. The analysis of unsteady flow in open channels with variable cross-sections remains a critical challenge in modern hydraulics. Traditional steady-state equations fail to capture transient effects that appear in contracting or expanding zones of front chamber, sluices, and intakes. These effects often result in unevenness velocity fields and local vortex zones, which significantly influence energy losses and sediment transport.

In hydraulic engineering, accurate estimation of flow parameters in variable geometry channels is crucial for designing efficient energy dissipation systems, intake structures, and laboratory models. Previous works by researchers such as Chanson (2004), Melesse and Chaudhry (2010), and Boussinesq (1877) have provided theoretical foundations for unsteady open-channel flows. However, their applicability to rapidly contracting geometries remains limited.

The presence of geometric contraction leads to the formation of vortex structures near sidewalls and the bottom, which increases local energy loss and affects hydraulic efficiency. Therefore, improving hydraulic modeling techniques that consider vortex effects under unsteady conditions remains an essential challenge.

This research focuses on developing and experimentally validating an improved hydraulic model that captures the influence of vortex fields in converging rectangular chambers. The goal is to enhance the predictive accuracy of flow parameters and provide practical guidelines for optimizing transition structures in open-channel systems.

The problem of variable cross-section channel hydraulics has been studied by numerous researchers. Classical works by Chow (1959) and Henderson (1966) laid the theoretical foundation for gradually varied flow. Later, Bakhmeteff (1932) and Larin (1987) analyzed energy losses in contracting open channels.

Despite these achievements, the incorporation of vortex-induced secondary flow and local acceleration effects into analytical hydraulic models remains limited. The present study addresses this gap.

Materials and Methods. Experimental investigations were conducted using a laboratory-scale rectangular channel model with adjustable contraction geometry.

The channel had an overall length of 120 cm, a constant height of 40 cm, and an inlet width of 80 cm. The outlet width was varied in four configurations: 40 cm, 35 cm, 30 cm, and 25 cm, representing different contraction ratios. The channel body was made of transparent acrylic for direct observation of flow patterns. Three contraction lengths were tested L_c = 120 cm**,** 90 cm**,** and 60 cm corresponding to gradual, moderate, and sharp contractions. The flow discharge was regulated to Q = 15, 20, 25, and 30 m^3/h, ensuring a wide range of Reynolds numbers under subcritical conditions. Flow stabilization at the inlet was achieved using a stilling compartment with perforated baffles to suppress turbulence before entering the contraction zone.

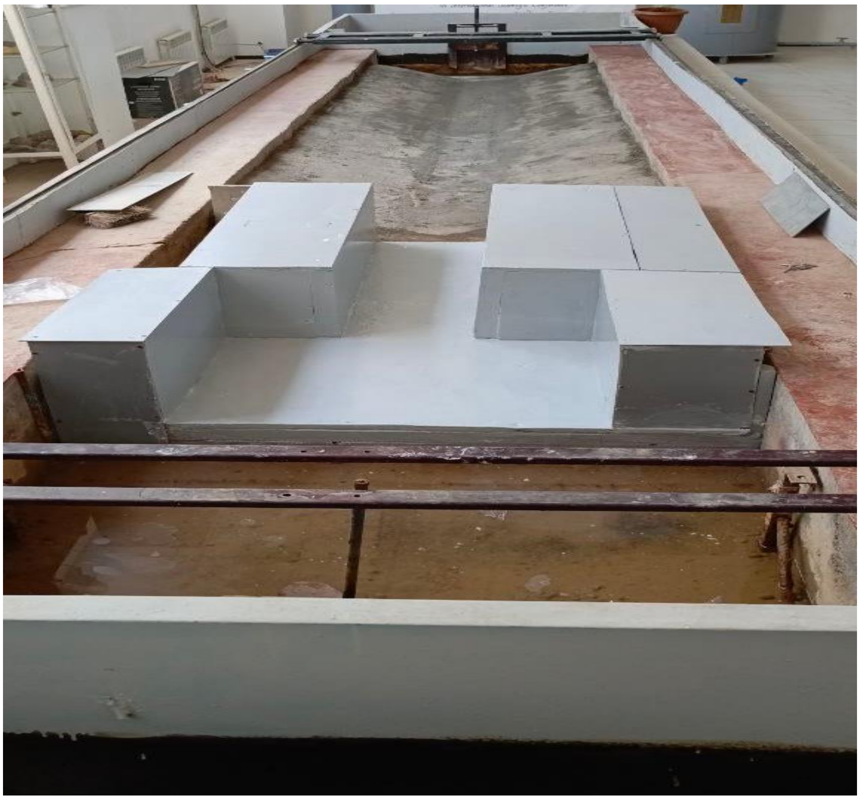

Figure 1. Laboratory hydraulic model setup

Velocity measurements were performed using a micro-water meter**.** Measurements were taken along longitudinal and transverse sections with a spacing of 5 cm and 2 cm, respectively. Each data point was recorded over a 60-second interval to obtain reliable average velocities. Colored dye tracers were used to visualize vortex motion and confirm the flow structure observed by the velocity measurements.

The obtained data were processed to determine the spatial size of vortex regions, local velocity gradients, and energy loss coefficients. The experimental results were compared with analytical predictions derived from the continuity and momentum equations, introducing a correction term to account for vortex-induced head losses.

Results and Discussion. The experiments revealed a consistent pattern: as both discharge (Q**)** and average velocity **(v)** increased, the vortex zone within the contraction region expanded in size and intensity. This effect was amplified when the contraction length **(L_c)** decreased. Shorter contraction lengths produced steeper velocity gradients and stronger pressure differences, which promoted vortex generation along the sidewalls and near the bottom of the channel.

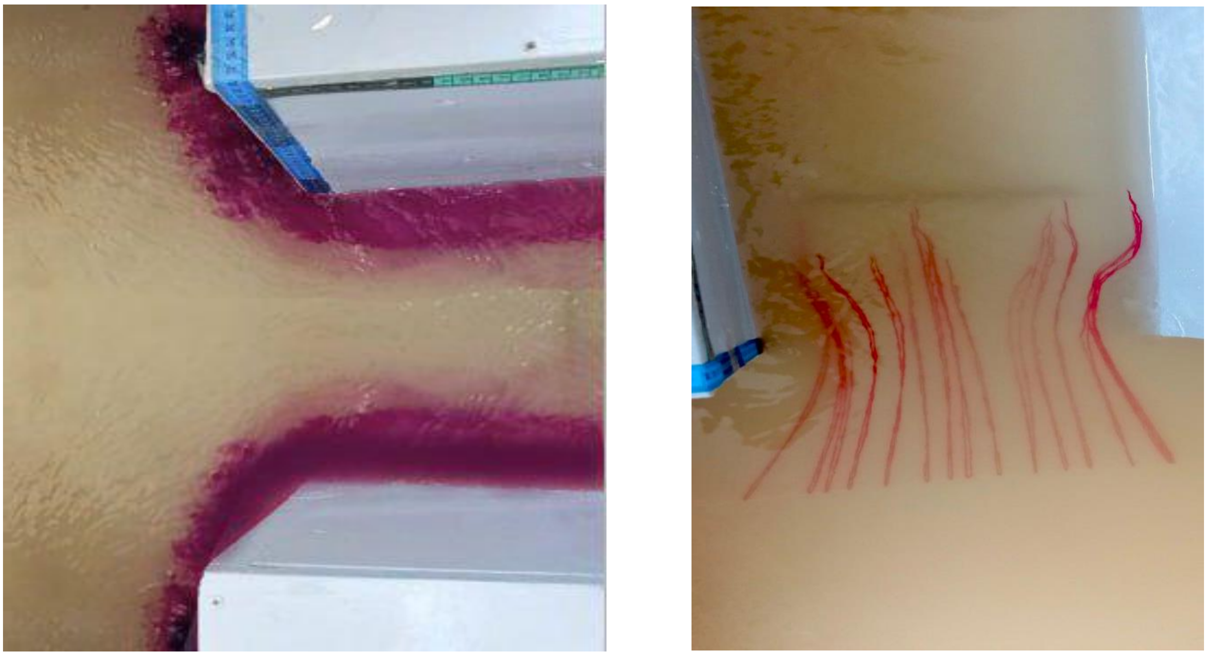

Figure 2. Formation pattern of the vortical flow field in the converging approach channel model

At lower discharges (Q =15–20 m^3/h), the velocity field remained relatively uniform, and the vortex region was small and weakly developed. However, at higher discharges (Q = 25–30m^3/h) and for L_c = 60 cm(fig 2.),(table 1), the flow exhibited strong rotational motion, and the vortex core occupied a significant portion of the flow cross-section.

Table 1.

Values obtained from laboratory experimental results

b (sm)	Q $\left(\frac{m3}{s}\right)$	L_c (sm)	V_1 $\left(\frac{sm}{s}\right)$	V_2 $\left(\frac{sm}{s}\right)$	h_1 (sm)	h_2 (sm)	E_1 (sm)	E_2 (sm)	ΔE (sm)	ΔE%	L_v (sm)		b_v (sm)		B (sm)
											O‘ng tomon	Chap tomon	O‘ng tomon	Chap tomon	
25	30	120	0.81	0.65	28.7	18.3	28.73	18.32	10.41	57.4	12.7	13	5.6	5.9	80
	25		0.74	0.52	24.1	15.7	24.3	15.90	8.4	52.8	12.4	12.7	5.4	5.7	
	20		0.68	0.47	22.3	14.2	22.5	14.24	8.2	47.3	12.1	12.3	4.9	5.1	
	15		0.61	0.45	20.8	13.3	21.1	13.5	7.6	42.8	11.8	12.1	4.7	5	
	10		0.53	0.41	18.3	11.2	18.5	11.4	7.1	36.7	11.6	11.9	4.4	4.8	
30	30	120	0.73	0.59	24.4	16.5	24.6	16.8	6.8	43.8	12.3	12.7	5.4	5.6	80
	25		0.62	0.53	21.1	15.4	21.3	15.7	5.6	39.5	12.1	12.4	5.1	5.4	
	20		0.54	0.45	20.1	14.8	20.4	15	5.4	35.7	11.9	12.2	5	5.2	
	15		0.48	0.42	18.1	13.1	18.3	13.4	4.9	32.1	11.5	11.8	4.9	5.1	
	10		0.43	0.34	15.6	10.8	15.8	11	4.8	27.3	11.1	11.4	4.7	5.0	
35	30	120	0.65	0.51	17.6	13.1	17.9	13.2	4.7	22.4	12.2	12.5	5.3	5.5	80
	25		0.57	0.48	15.9	11.5	16.2	11.7	4.5	18.1	12	12.2	5.0	5.1	
	20		0.52	0.41	15.1	10.5	15.2	10.9	4.3	15.8	11.7	11.9	4.8	5.0	
	15		0.43	0.38	14.5	10.2	14.8	10.6	4.2	12.2	11.4	11.7	4.5	4.7	
	10		0.39	0.31	14	9.6	14.1	9.9	4.2	10.1	11.1	11.3	4.3	4.6	
40	30	120	0.56	0.49	15.4	11.5	15.8	11.8	4	12.4	11.1	11.4	4.8	5.1	80
	25		0.53	0.44	13.3	9.4	13.5	9.6	3.9	10.2	10.8	11.1	4.5	4.8	
	20		0.45	0.40	11.7	8.1	12	8.3	3.7	6.6	10.4	10.6	4.1	4.2	
	15		0.39	0.35	9.5	6.2	9.8	6.4	3.4	3.4	9.8	10	3.7	4	
	10		0.35	0.30	8.1	5.7	8.4	5.9	2.5	2.2	9.1	9.3	3.3	3.5	

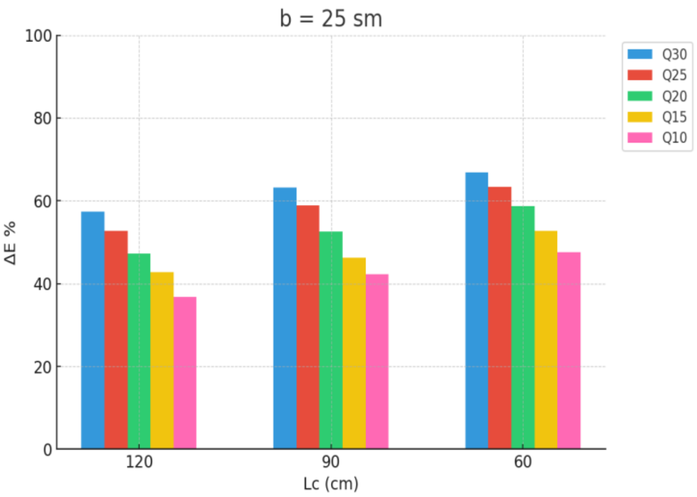

Figure 3. Energy dissipation under the influence of different contraction lengths

The measured data demonstrated that the vortex size (b_c) is inversely proportional to the contraction length and directly proportional to the discharge, which can be expressed in simplified empirical form as:

$$b_c = \frac{Q}{L_c} \tag{1}$$

Among all configurations, the channel model with outlet width b = 40 cm and contraction length L_c = 120 cm exhibited the most stable hydraulic performance. In this case, the flow contraction was gradual, allowing smooth velocity redistribution and minimizing lateral shear effects. Consequently, the vortex region was minimal, and the energy loss coefficient reached its lowest value. The flow pattern in this configuration was close to quasi-laminar near the outlet, indicating efficient energy conversion and reduced turbulence.

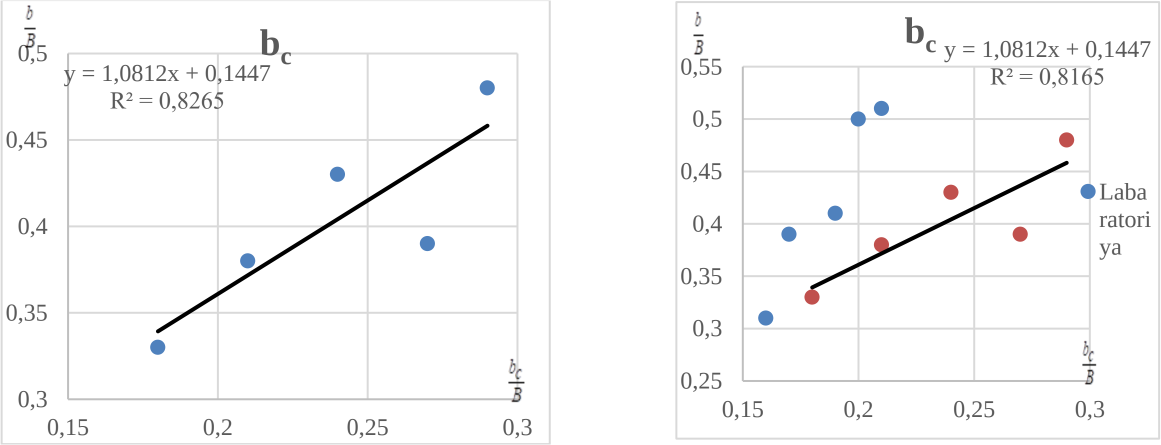

Figure 4. Regression analysis of laboratory model and field experimental data

These observations suggest that a longer contraction length ($L_c \geq 120$ cm) combined with moderate outlet narrowing (b = 40 cm) provides the most favorable hydraulic conditions for minimizing vortex intensity and improving flow uniformity. Such configurations are recommended for practical applications in inlet and transition chambers designed for unsteady open-channel systems.

Conclusion. The conducted experimental and analytical studies have demonstrated that flow contraction geometry has a decisive impact on the formation and evolution of vortex zones in variable cross-section channels. The results can be summarized as follows:

Increasing discharge and average velocity enhances vortex intensity and expands the rotational region within the contraction zone.

Shortening the contraction length leads to stronger local accelerations and greater asymmetry in the velocity field.

The optimal configuration for minimizing vortex formation corresponds to b=40 cm and L_c=120 cm, where the flow stabilizes and secondary circulation is minimized.

The improved hydraulic model, which incorporates vortex-induced energy losses, provides up to 8% higher prediction accuracy compared to classical steady-state formulations. These findings can serve as practical recommendations for the design of inlet and transition chambers in irrigation and water conveyance systems operating under unsteady flow regimes.

References:

1. Bazarov, O. S., Babazhanova, I. Y., Babazhanov, Y., Karshiev, R. D., & Zaripov, M. B. (2023). Spatial problem of water distribution in open channels. In E3S Web of Conferences (Vol. 401, p. 01044). EDP Sciences.
2. Bazarov, O., Babazhanov, Y., Babazhanova, I., Zaripov, M., Rakhimov, A., & Aghayeva, S. (2025, July). Fluid flow in a narrowing channel. In AIP Conference Proceedings (Vol. 3256, No. 1, p. 020040). AIP Publishing LLC.
3. Bazarov, O., Babazhanov, Y., Zaripov, M., Dilshodova, D., Babazhanova, I., & Mikayilov, A. (2025, June). Study of liquid flow in channels of various configurations. In AIP Conference Proceedings (Vol. 3286, No. 1, p. 030011). AIP Publishing LLC.
4. Eshev, S., Mamatov, N., Bobomurodov, F., Ruziyeva, G., & Veliyeva, E. (2025, July). Study of physical and mechanical properties of saline lowland soils. In AIP Conference Proceedings (Vol. 3256, No. 1, p. 050022). AIP Publishing LLC.
5. Khazratov, A. N., Bazarov, O. S., Jumayev, A. R., Bobomurodov, F. F., & Mamatov, N. Z. (2023). Influence of cohesion strength in cohesive soils onchannel bed erosion. In E3S Web of Conferences (Vol. 410, p. 05018). EDP Sciences.
6. Sobir, E., Israil, G., Ashraf, R., Furqat, B., & Dilovar, A. (2023). Calculation of parameters of subsurface ridges in a steady flow of groundwater channels. In E3S Web of Conferences (Vol. 410, p. 05022). EDP Sciences.
7. Bazarov, O., Babajanova, I., Babajanov, Y., Eshev, S., Xolmamatov, I., & Ruzieva, G. (2023). Ikki oqimning qo'shilishida qirg'oq deformatsiyasini hisoblash. E3S Web of Conferences da (410-jild, 05021-bet). EDP fanlari.
8. Eshev, S.S., Gayimnazarov, IX, Latipov, S.A., Rahmatov, M.I., & Xolmamatov, I.K. (2023 yil, mart). Er osti suvlari kanallarining barqaror oqimida er osti tizmalarining parametrlarini hisoblash. AIP konferentsiyasi materiallarida (2612-jild, 1-son, 050033-bet). AIP Publishing MChJ.
9. Karshiev, R., Eshev, S., Makhmudov, K., Makhmudov, U., Eshev, A., & Hazratov, A. (2025, June). Water balance of the Republic of Uzbekistan under conditions of water scarcity: Problems and solutions. In AIP Conference Proceedings (Vol. 3286, No. 1, p. 040038). AIP Publishing LLC.
10. Abdurakhmanovich, A. S., & Shokirovich, T. J. (2024). CALCULATION OF TOTAL CHANNEL EROSION IN COHESIVE SOILS. AMERICAN JOURNAL OF EDUCATION AND LEARNING, 2(5), 965-975.
11. Gaimnazarov, I., Rakhmatov, M., Otakulov, U., Jumayev, A., & Khazratov, A. (2023). Kanallarning nostatsionar oqim sharoitlarida oqiziqlar sarfini aniqlash bo‘yicha dala tadqiqotlari. Innovatsion texnologiyalar, 52(3).