Characteristical analysis of tidal and residual currents in the sea area around Tangshan international tourism island

Jinzi Yang¹, Wenping Ding¹, *, Jiaxing Cui², and Shan Guo²

¹Hebei Institute of Geological Survey, Shijiazhuang, China
²Land and resources exploitation center of Hebei geological and mineral bureau, Shijiazhuang, China

*Corresponding author: wenpingding@hbigs.org

Abstract. For the sea area around Tangshan international tourism island, continuous conservation of ocean current at 3 stations were carried out. The harmonic analysis was conducted based on the measured data. According to the harmonic analysis results, the flow velocity, type, movement form of tidal current and residual current distribution were researched finely. The results show that the sea area was dominated by regular semi-diurnal tidal currents. The movement form of tidal current was reciprocating current, and the trend of residual current presented regional differences. The research had an important practical significance for the resource development and marine engineering construction of the sea area.

Keywords: Tangshan international tourism island, tidal current, residual current, reciprocating current.

1. Overview of the study area
Tangshan international tourism island is located in the coastal zone on the northern edge of the Bohai bay in the southern coast of Tangshan city, while on the southwest side of the Luan river estuary. It is composed of three islands, Bodhi Island, Moon Island, and Xiangyun Island, and the northern land area [1-3]. The study area is shown in Figure 1. The total area is 125.64km², of which the island area is 39.76km² and the land area is 85.88km². The island has distinctive landscape features, excellent resource endowments, and diverse vegetation types. It is a key area for marine environmental protection and resources scientific utilization in Hebei province.
2. Observation methods

In order to obtain the characteristics of the tidal current in the study area, continuous observation at 3 stations was carried out. The station distribution was shown in Figure 1. The spring tide time was September 14-15, 2015, and the neap tide time was October 23-24, 2015.

The observation instrument was a direct reading current meter, the continuous observation time was 25 h, and the observation frequency was 1 time/h. The measured results of current velocity and current direction were the average velocity and main flow direction of 3 minutes. In order to eliminate the influence of the hull on the surface flow, the surface was set to 1m below the water surface. The hull position was measured by every 3h to prevent anchoring, and the water depth was measured by each hour. According to the on-site water depth conditions, the surface layer was only observed at stations S1 and S2, while the surface and bottom layers were observed at station S3.

3. Results and analysis

3.1. Current velocity and direction

During the spring tide and neap tide, the current velocity and direction at 3 observation stations were measured, shown in Table 1 and Table 2.

Table 1. Flow velocity of each observation station during the spring tide

| Observation station | Layer | Maximum flow velocity of high tide(cm/s) | Maximum flow direction of high tide(°) | Maximum flow velocity of ebb tide(cm/s) | Maximum flow direction of ebb tide(°) |
|---------------------|-------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| S1                   | surface | 89                                     | 318                                    | 67                                     | 152                                    |
| S2                   | surface | 62                                     | 272                                    | 40                                     | 98                                     |
| S3                   | surface | 55                                     | 266                                    | 52                                     | 82                                     |
| S3                   | bottom  | 48                                     | 260                                    | 41                                     | 84                                     |
Table 2. Flow velocity of each observation station during the neap tide

| Observation station | Layer | Maximum flow velocity of high tide(cm/s) | Maximum flow direction of high tide(°) | Maximum flow velocity of ebb tide(cm/s) | Maximum flow direction of ebb tide(°) |
|---------------------|-------|------------------------------------------|----------------------------------------|----------------------------------------|----------------------------------|
| S1                  | surface | 67                                       | 328                                    | 46                                     | 154                              |
| S2                  | surface | 49                                       | 282                                    | 38                                     | 122                              |
| S3                  | surface | 70                                       | 252                                    | 43                                     | 64                               |
| S3                  | bottom  | 71                                       | 252                                    | 34                                     | 104                              |

From Table 1 and Table 2, it can be seen that the flow velocity from the estuary to the island outer firstly decreased and then increased, and the surface velocity was greater than the bottom velocity. Comparing the two periods, whether it was the high tide or ebb tide, the flow velocity of the spring tide was greater than that of the neap tide.

According to the observation data at each station, the surface velocity and flow direction curves were obtained, as shown in Figure 2 and Figure 3.

![Figure 2](image1.png)

**Figure 2.** Surface velocity and flow direction change diagram at station S1 during the high tide

![Figure 3](image2.png)

**Figure 3.** Surface velocity and flow direction change diagram at station S1 during the low tide
3.2. Tidal current type

Tidal current usually referred to the seawater flow caused by the rise and fall of astronomical tides [4]. The maximum flow velocity ratio of the main tidal current was used as the basis for type division [5]. The tidal current type coefficient $F$ was described as

$$F = \frac{W_{K_1} + W_{O_1}}{W_M}$$

(1)

Where, $W_M$, were respectively the major semi-elliptical axis of the main lunar semi-diurnal tidal current, the lunar solar declination diurnal tidal current and the main lunar diurnal tidal current.

When $0 < F \leq 0.5$, it is a regular half-day trend. When $0.5 < F \leq 2.0$, it is an irregular half-day trend. When $2.0 < F \leq 4.0$, it is an irregular daily trend. When $F > 4.0$, it is a regular daily trend.

Table 3. Tidal current type coefficients of 3 stations

| Observation station | Layer     | $F$ (spring tide) | $F$ (neap tide) |
|---------------------|-----------|-------------------|-----------------|
| S1                  | surface   | 0.42              | 0.50            |
| S2                  | surface   | 1.23              | 0.54            |
| S3                  | surface   | 0.37              | 0.49            |
| S3 bottom           |           | 0.32              | 0.51            |

From Table 3, the tidal current type coefficients of at station S1 and S3 were less than or equal to 0.5 during spring tide and neap tide, While that were 1.23 and 0.54 at station S2. Therefore, the sea area was dominated by regular semi-diurnal tidal current. The position between Xiangyun Island and Moon Island was an irregular half-day trend current.

3.3. Movement form of tidal current

The movement form of tidal current can be expressed by the elliptical rotation rate $K$. $K$ is the ratio of short ellipse axis to long ellipse axis of the tidal current. When the absolute value of $K$ is greater than 0.25, the tidal current shows strong rotation. When the absolute value of $K$ is less than 0.25, the tidal current was dominated by a reciprocating current. A positive value of $K$ means that the tidal current moves counter clockwise, and a negative value means that it moves clockwise [6].

According to the harmonic analysis results, the elasticity $K$ of the M2 sub-current of each layer was calculated as shown in Table 4.

Table 4. $K$ values of the M2 sub-current at 3 stations

| Observation station | Layer | $K$ (spring tide) | $K$ (neap tide) |
|---------------------|-------|-------------------|-----------------|
| S1                  | surface | 0.01              | 0.04            |
| S2                  | surface | 0.11              | -0.06           |
| S3                  | surface | -0.11             | -0.09           |
| S3                  | bottom  | 0.03              | 0.22            |

It can be seen from Table 4, the $K$ value of each station was less than 0.5, so the movement form was a reciprocating flow. The flow direction during the high tide and ebb tide were relatively fixed, and there was no rotation characteristics. The $K$ values of the surface current at the S3 station were both negative, showed a clockwise movement characteristics. The vector diagrams of the surface current at 3 stations during the spring tide and neap tide were respectively shown in Figure 4 and Figure 5.
Figure 4. Vector diagrams of surface currents at 3 stations during the high tide

Figure 5. Vector diagrams of surface currents at 3 stations during the neap tide

From Figure 4 and Figure 5, the characteristics of the reciprocating flow can be seen intuitively. The flow direction of the station S1 and station S2 was from northwest to southeast, and that of the station S3 was from east to west.

3.4. Residual current distribution
The measured tidal current included periodic tidal current and non-periodic residual current. The residual current was mainly caused by circulation, weather and topographic factors. The flow direction of residual current is often the direction of sediment movement and the pollutants transport. Residual current analysis is an effective method for research on coastal sediment movement and environmental protection projects [7-8]. After harmonic analysis, the residual current was separated. The distribution
characteristics were shown in Table 5. The vector diagram of the surface residual current of each observation station during the spring tide and neap tide were respectively shown in Figure 6 and Figure 7.

**Table 5.** Residual current distribution characteristics of each observation station

| Observation station | Layer | flow velocity of spring tide(cm/s) | flow direction of spring tide(°) | flow velocity of neap tide(cm/s) | flow direction of neap tide(°) |
|---------------------|-------|-----------------------------------|---------------------------------|---------------------------------|-------------------------------|
| S1                  | surface | 4.2                               | 210.6                           | 4.8                             | 184.7                         |
| S2                  | surface | 6.6                               | -37.9                           | 4.1                             | 176.2                         |
| S3                  | surface | 6.5                               | -85.8                           | 1.8                             | -39.8                         |
| S3 b                | bottom  | 5.2                               | 238.7                           | 2.8                             | 264.1                         |

**Figure 6.** The vector diagram of the surface residual current during the spring tide

From the table 5, Figure 6 and Figure 7, the largest residual current during the spring tide was at station S2 between the islands, with a flow velocity of 6.6 cm/s and a flow direction of -37.9°. The residual current at station S3 off the island was similar to that of S7, and the flow direction was northwest. The smallest residual current during the spring tide was at station S1, and the flow direction was west. The largest residual current during the neap tide was at station S1 near the Daqing River, with a flow velocity of 4.8 cm/s and a flow direction of 184.7°. The residual current at station S3 outside the island was the smallest, where the direction was northwest. The flow direction at station S2 was southeast.
Figure 7. Vector diagrams of surface residual currents during the neap tide

4. Conclusions
(1) The sea area was dominated by a regular half-day tide, and the station S2 between Xiangyun Island and Moon Island was an irregular half-day tide.
(2) The tidal current movement form was a reciprocating flow according to the elliptical rotation rate $K$. The $K$ values were all small, so the reciprocating flow characteristics were obvious, and no flow direction rotation characteristics was performed.
(3) The residual current was separated from the harmonic analysis, so the appeared position, flow velocity, flow direction of the maximum residual current and the minimum residual current during the spring tide and neap tide were obtained.

References
[1] Zhen Yanlong, Zhang Miaoxin. Suggestions on ecological restoration project of Tangshan international tourism island [J]. Ocean Development and Management, 2019, (7): 53 - 57.
[2] Wang Ligui, Jia Xufei, Zhang Ran. Research on development and exploitation of Tangshan bay international tourism island based on WorldView-2 satellite remote sensing images [J]. Ocean Development and Management, 2015, (9): 85 - 89.
[3] Kang Jing. The division of functions of Tangshan bay three islands [D]. Qingdao: The first institute of oceanography, Soa, 2011.
[4] Xu Huifen, Jiang Bo, Zhao Shiming, et al. Analysis of hydrological Environment of Tianjin Coast [J]. Ocean Technology, 2011, 30 (2): 63 - 68.
[5] Xu Shanshan, Yang Jinkun, Wu Shuangquan, et al. Characteristics of surface tidal and residual currents of the central Bohai Sea [J]. Marine Science Bulletin, 2017, 36 (2): 128 - 134.
[6] Yang Wankang, Yuan Di, Zhang Junbiao, et al. Characteristics of surface tidal and residual current around the Da-men and Xiao-men islands, Marine Sciences, 2014, 38 (7): 76 – 81.
[7] Chen Qian, Huang Daji, Zhang Benzhaol, et al. Characteristics of the tidal current and residual current in the seas adjacent to Zhejiang [J]. Donghai Marine Science, 2003, 21 (4): 1 - 14.
[8] Zheng Binxin, Li Jiufa, Zeng Zhi, et al. Characteristical analysis of tidal and residual currents in Beilun Estuary [J]. Journal of Oceanography in Taiwan Strait, 2012, 31 (1): 121 - 129.