Experimental investigation on flow patterns induced by a twin-block perforated artificial reef

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ABSTRACT

Artificial reefs are common human-made structures placed purposefully on the seabed for fishery enhancement and coastal protection. The local flow patterns could be further created and designed by perforated artificial reefs to become more inhabitable for different fish species, which attracts more attentions from researchers. Thus, based on the Particle Image Velocimetry (PIV) technology, the primary focus of this research is to investigate the flow field of perforated artificial reefs arranged longitudinally with two perforated blocks, and to compare with the flow field of the single reef with the same structure. The results show that, the turbulent flow regime inside and outside the twin-block perforated reef consists of vortices interaction patterns and the main flow becomes weaker along the current direction. Several vortices with different scales are formed inside and behind the reef, and the vortex structure displays certain symmetry in the transverse direction because of symmetrical reef structure. Comparing with the flow field of a single perforated reef, the increase in reef number has little effect on the vertically vortical structure within the reef compartments. However, the influence range and sheltering effect induced by the twin-block reef becomes greater than that in the single reef. This research reveals the geometrical relationship between perforated reef structure and internal flow pattern, and provides a scientific guidance for optimizing the structure and deployment of perforated artificial reefs.

KEY WORDS: Flow pattern; artificial reef; PIV; vortices

INTRODUCTION

Artificial reefs are common human-made structures, which are deployed on the seabed to emulate some features of natural reefs, such as protecting, concentrating and enhancing populations of fish. Since the early of 19th century, when artificial reefs began to be used for proliferation of marine fishery and restoration of ecological environment, a great deal of researches of artificial reefs have been focused on the biological, chemical and marine environment aspects (Simon et al., 2011; Chen et al., 2019; Gates et al., 2019; Wu et al., 2019).

Ecological function of artificial reefs is mainly realized by the use of fish’s own rheotaxis, which is a behavior leading them to stay someplace they prefer rather than being swept downstream by the current (Oteiza et al., 2017). The deployment of artificial reefs can alter local flow fields, reform the surrounding sediment distribution and facilitate accumulation of organic materials circulation (Ambrose and Anderson, 1990). The diversified flow patterns varied by artificial reefs well cater to the fish’s rheotaxis and stimulate fish to migrate near artificial reefs (Paxton et al., 2019). In recent years, the function of artificial reefs on disturbing the flow is well recognized, so that the growing interest in artificial reefs is owing to its hydrodynamic performance.

Perforated artificial reefs are one of the most widely utilized reefs configuration since its complex structure and abundant internal compartment that enriches the diversity of flow structure, which provides an ideal habitat for reef fish that prefer varied flow fields. The flow field of a perforated artificial reef is mainly composed of three parts: upwelling formed in front of the stoss face, wake formed in the lee side and internal turbulent flow within the compartment of reef. The upwelling and wake vortices can facilitate the supply of bottom nutrients and provide shelter for marine species, respectively (Kim et al., 2017; Jiang et al., 2019). Since the development of upwelling and wake vortices near reefs is significant and the scale is easy to quantify for analysis, most of scholars focus on the scale of local upwelling and backflow by changing some external conditions (such as inlet velocity, impacted angle and structure shape, etc.) to examine the optimal reefs configuration in recent years (Liu et al., 2012; Liu and Su, 2013; Li et al., 2017; Wang et al., 2018).

Actually perforated artificial reefs can form valuable habitats within internal compartments, supporting greater species richness and diversity than external surfaces exposed to higher hydrodynamic forces (Su et al., 2008), because their internal complex turbulent flow structure can satisfy preference of different aquatic organisms. However, the investigations on internal turbulence of artificial reefs are found to be limited. Especially the complex vortex structure inside the reefs, which is directly connected with the current exchange, materials deposition and energy dissipation, lacks of detailed research.

Traditionally, detail investigations on flow patterns inside artificial reefs are not easy to obtain by means of experimental method due to the limitation of equipment technique. At present, most researches are based on numerical models due to their versatile and cost-effective. However, there is always a gap between simulation results and actual situation. Accordingly, the experimental research on turbulent flow patterns induced by artificial reefs is still quite necessary.

The artificial reefs are widely utilized along coastline of China for nearly