Hydrodynamic Flow Separation Control through Vortex Generators

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ABSTRACT

Flow separation is a major cause of the unexpected drag increase in marine structures. The experimental study of hydrodynamic flow separation control through vortex generators (VGs) was conducted in Shanghai Jiao Tong University. Vortex generators have been widely used in aircraft industry to prevent or delay flow separation over wings. The function of VGs is to introduce vortices into the flow ahead of the separation point to energize the boundary layer and thus to delay the flow separation. The application results on a surface-piercing cylinder and an AHTS ship model demonstrate the VGs effectiveness in resistance improvement of marine structures.

KEY WORDS: Flow separation control; vortex generators; resistance improvement; marine structures.

INTRODUCTION

Flow separation accompanied with the large energy losses is a major cause of the unexpected drag increase in marine structures. The effective control of the flow separation remains important for the resistance improvement of the marine structures.

Various flow control methods have been investigated and studied in the past decades. Vortex generators (VGs), first introduced by Taylor (1947), have been widely used in aircraft industry to prevent or delay flow separation over wings. Conventional VGs consist of a row of small plates that project normal to the surface and are set an angle of incidence to free-stream. The function of VGs is to introduce vortices into the flow ahead of the separation point to energize the boundary layer and thus to delay the flow separation. The simplicity and the effectiveness of VGs have attracted a great deal of attention in the aerospace community. They seem to be a logical choice as a potential method to control the hydrodynamic flow separation on the marine structures.

Compared with the airfoil operation in the air, the marine structures usually operate on the water surface. The existing free surface complicates the flow separation problem (Chow, 1967; Stern et al., 1989). Current research mainly focus on the physical mechanism of wave-induced separation (Metcalf et al., 2006), but very few on flow control and resistance improvement. The motivation of this research is to explore the possible application of VGs on the marine structures to improve the resistance performance.

METHOD FOR FLOW SEPARATION CONTROL

Flow Separation Detection

The effective flow separation control requires the accurate detection of the separation region. Theoretically, the separation is indicated by the vanishing of the skin friction on the surface. Achenbach (1968) studied the skin friction and static pressure distribution of the circular cylinder in cross-flow. The obtained results shown in Fig. 1 reveal that the zero skin friction position corresponds to the constant pressure distribution. The flow separation region is thus indicated by the constant pressure feature, and the separation line could be determined as the initial location of the constant pressure region. This detection criterion has been widely used in the separation study of the airfoils (Bragg and Gregorek, 1987).

Fig. 1. Circular cylinder: skin friction and pressure distribution. Re=10^5