

Numerical predictions of flow structure for a circular cylinder with exterior surface dimples

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ABSTRACT

Water flow around a circular cylinder with exterior surface dimples is numerically predicted using version 6.3.26 of FLUENT. Dimples are used on the internal or external surface for heat transfer augmentations and drag reductions. Spherical medium dimples (the dimple depth/the dimple print diameter=0.2) are located on the exterior of a circular cylinder. Two-dimensional flow structure is analyzed around the circular cylinder. The drag coefficient of a dimpled cylinder is calculated and compared to the data of a circular bare cylinder.

KEY WORDS: Circular cylinder, dimpled cylinder, drag coefficient, drag reduction

INTRODUCTION

The deep-sea mining system is comprised of three different parts : seafloor collecting system, lifting system and a mining ship(Chung, 1994). The lifting system is employed for lifting manganese nodules from the seabed to the mining ship. This lifting system is a set of devices, for example, hydraulic pumps, lifting pipes, a buffer and flexible hoses. The cross-section of the lifting pipes usually is circular. The flow of sea water makes the pipes vibrate, which results in additional problems and technical difficulties. The reduction of drag of these cylinders is one solution for this vibration problem.

Of the recent investigations that research flow structure characteristics over a cylinder and dimples, Chung et al.(1994) present the means of reducing vortex-shedding-induced vibration of a deep-ocean mining pipe of 6000 m in length and the measurement of flow-induced torsional moment of the pipe. Five basic configurations are experimented: bare cylinder, cylinder with perforated shroud, cylinder with straight two cables and strakes, cylinder with straight three cables and strakes, and cylinder with strakes. According to these investigators, the strake model with electromagnetic (EM) power cables and a cylinder model with a perforated shroud show the least vortex-shedding

intensity and minimum increase in drag. Bearman et al.(1993) report the drag coefficient and the Strouhal number of a dimpled circular cylinder over the Reynolds number of 2×10^4 to 3×10^5 . The ratio of the depth of the dimples to the dimple print diameter is 9×10^{-3} . The authors describe that a dimpled circular cylinder has a lower drag coefficient than a smooth cylinder over the Reynolds number of 4×10^4 to 3×10^5 .

Kimura et al.(1991) show a groove on the circular cylinder moves the separation point backward and reduces drag even at low Reynolds number. Three types of grooves (depth of dimple/dimple print diameter = 0.21, 0.15, and 0.09) are studied. The most effective positions of the grooves are about 80° measured from the foremost point of the cylinder, according to the authors.

For the study of flow structure due to dimple depressions on a flat plate, Ligrani et al.(2001) presents instantaneous, dynamic and time-averaged characteristics of the vortex structures above and from the dimples on one wall of a channel. Flow visualization images and the experiment data are given. The primary vortex and secondary vortex pairs augment the normalized Reynolds normal stress ($\overline{u'^2}/U^2$). Sherrow et al.(2006) presented the effects of adding spherical-indentation dimples to the exterior surfaces of tubes in a crossflow heat exchanger. The ratio of the dimple depth to the dimple print diameter is 0.1 and 0.4. Significant heat transfer augmentations are reported.

The numerical solutions presented in this article provide additional information on flow structure in a dimpled channel surface, a 2-D pure cylinder, and a 2-D dimpled cylinder

NUMERICAL PROCEDURES

The FLUENT numerical code, version 6.3.26 (called "PROGRAM" in this paper) is employed for all numerical simulations. GAMBIT 2.3.16 is used for the numerical grid.

Turbulence modeling