# NUMERICAL MODELLING OF THE EFFECT OF THE GREEN VALVE ON AIR ENTRAINMENT AT HOPPER OVERFLOW

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## INTRODUCTION

When a dredge mixture deserts a hopper through its overflow structure, often significant volumes of air are entrained into the mixture. The air entrainment is a result of "hydraulic jump" turbulence generated in the core of the (often circular) overflow structure. The near-field sediment processes are important as they feed the more far-reaching dredge plumes. Once discharged, the trapped air tends to segregate from the overflow plume owing to its buoyancy and the rising of bubbles towards the surface of the sea is reported to have a pronounced effect on near-field dispersion and to obstruct settling of the mixture sediments (Parys et al., 2000).

*Figure 1 _ left: overflow plume , right: annual hydraulic jump at overflow*

The near-field dispersion weakens the strength of the density current which is highly undesirable as it increases the foot-print of the dredge plume. Plumes with high levels of turbidity may have severe impacts on coastal environments, and dredge operations are therefore often forced to reduce production rates to reduce dredge plume foot-prints in order to comply with environmental regulations. One of the more recognized measures in reducing plume footprints is combating air entrainment with the so-called green valve device, also known as the environmental valve (Jan de Nul, 2003). The green valve is rigged within the shaft of the overflow structure and the fundamental idea is to increase the hydraulic resistivity inside shaft leading to increased submergence of the overflow, which results in less air entrainment (Jain et al. 1978).

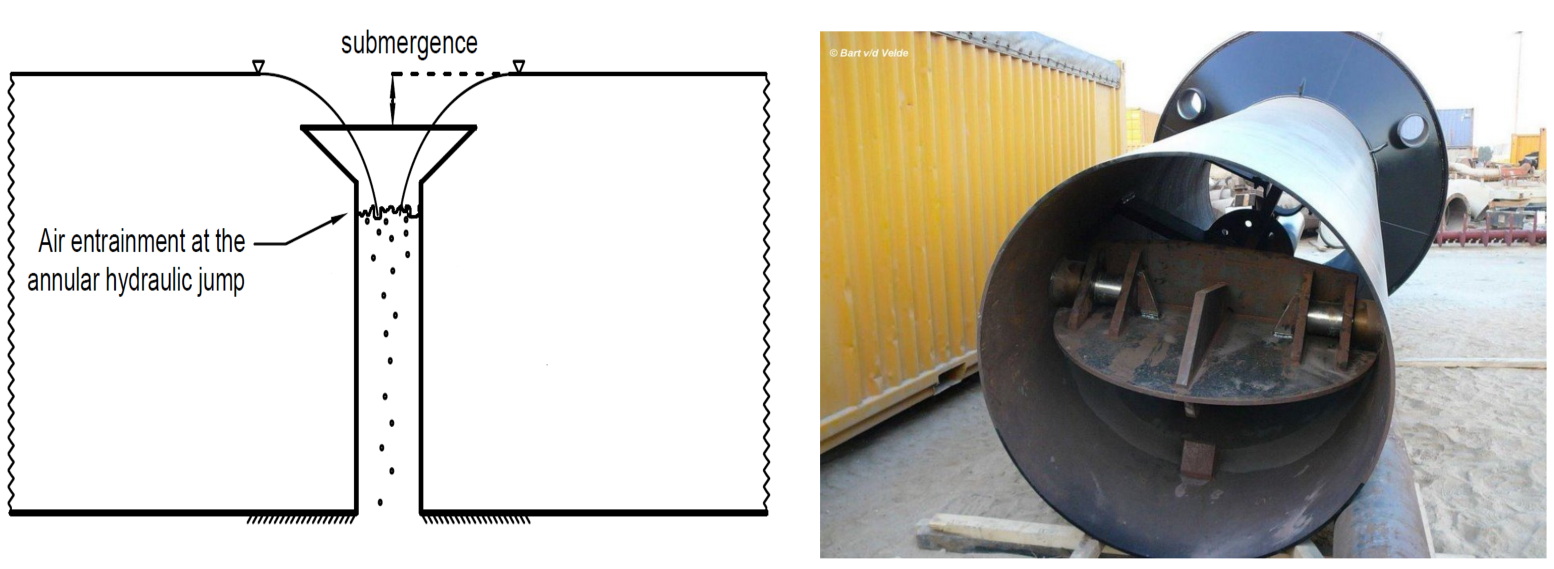


*Figure 2 _ left: schematic figure of overflow shaft , right: Green valve*

## PRESENT WORK AND RESULTS

The hydraulics of the dropshafts (being in close resemblance to the hopper overflow structures) has been studied for better understanding of the air entrainment process and the driving parameters. A two-phase numerical model, implemented in OpenFOAM libraries, based on the Volume of Fluid (VOF) method (Hirt and Nichols, 1981), has been established to simulate the process of overflow and the air entrainment in circular dropshafts, which has been verified successfully with the experimental data (Whillock and Thorn, 1973). The model has been used to simulate the performance of the so called Green Valve, as being a mitigation method in reducing the air entrainment in overflow pipes. The numerical results confirm the effectiveness of the valve in reducing the rate of entrainment of the air bubbles into the overflow. The presence of the valve causes an extra hydraulic resistance to the flow passing through the shaft and reduces the flow rate. This reduction results in smaller Froude numbers inside the shaft and therefore reduces the critical submergence at the shaft intake which then results in less air entrainment.

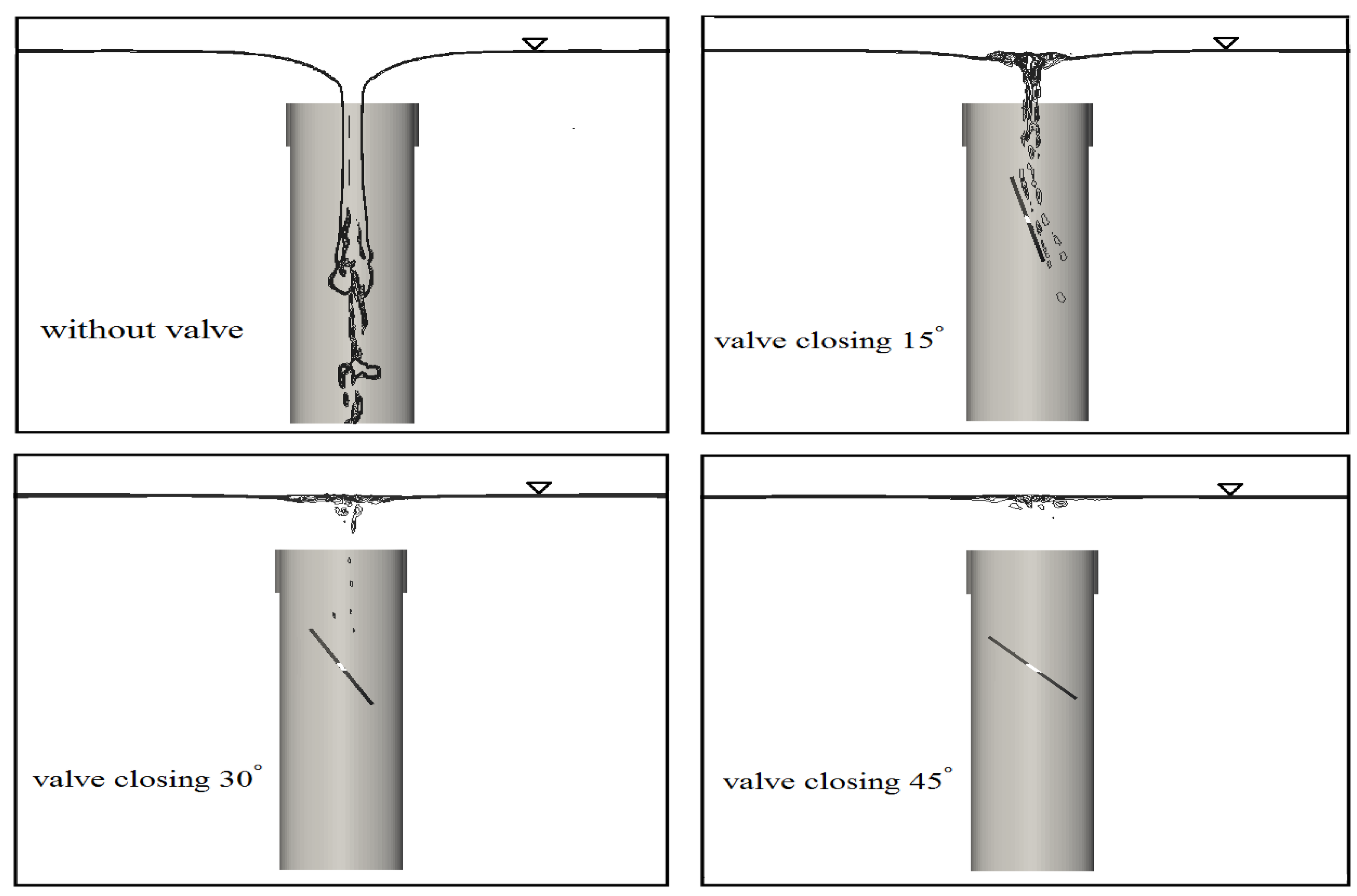


*Figure 3_ Air-water interface from the CFD results*

The results from the numerical model also show the reduction in the flow rate through the shaft, which has always been considered as a draw back of using the green valve. However, the results tell that the rate of reduction in the air entrainment due to closure of the valve is far more higher than the relative reduction in the flow rate for the corresponding valve closure.

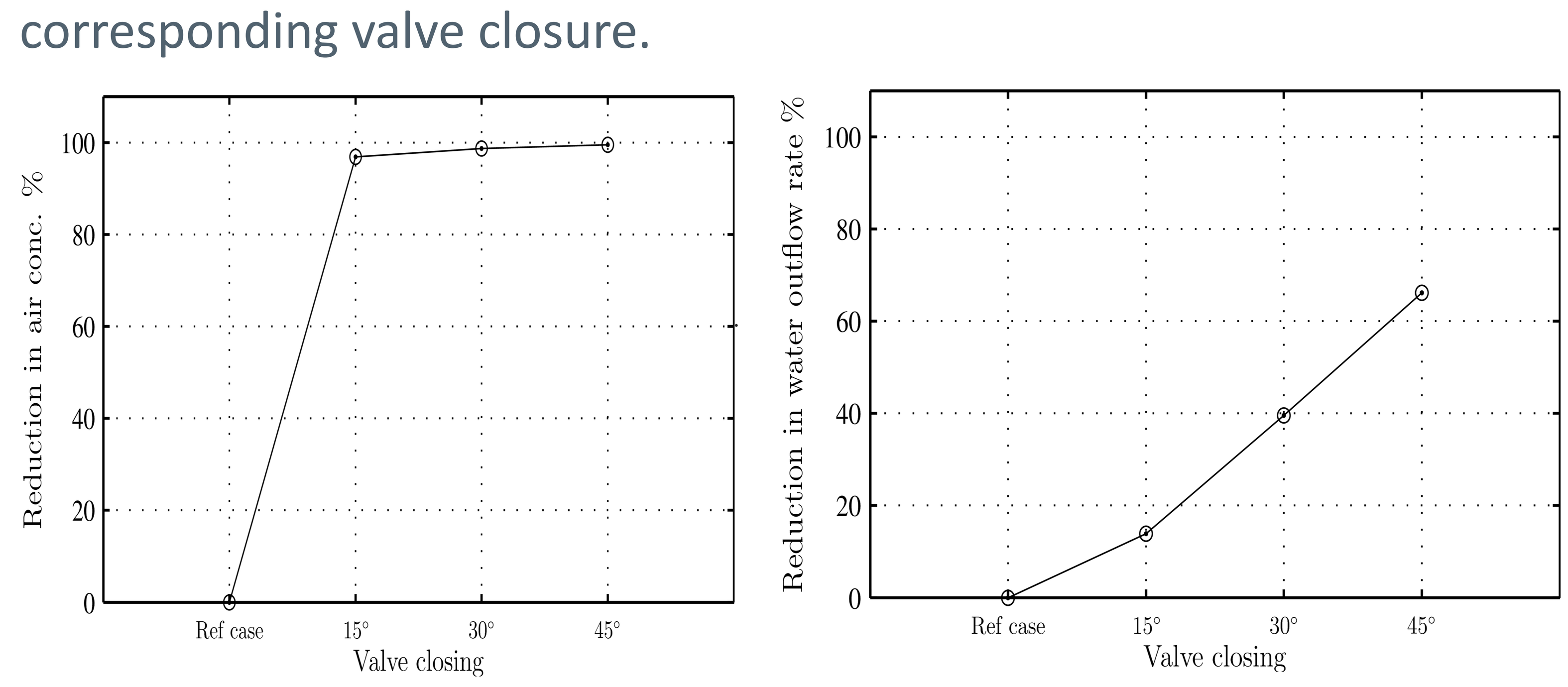


*Figure 4_ Reduction in air entrainment (left) and water flux (right)*

**REFERENCES**

Hirt, C. and Nichols, B. (1981). "Volume of fluid (VOF) method for the dynamics of free boundaries." Journal of Computational Physics, 39(1), 201–225.

Jain, A., Garde, R., and Raju, K. R. (1978). "Air entrainment in radial flow towards intakes." Journal of the Hydraulics Division, 104(9), 1323-1329.

Jan de Nul (2003). "SPECIALISED ALTERNATIVE DREDGING METHODS." 3er Congreso Argentino de Ingenieria Portuaria.

Parys, M. V., Dumon, G., Pieters, A., Claeys, S., Lanckneus, J., Lancker, V. V., and Vangheluwe, M. (2000). "Environmental monitoring of the dredging and relocation operations in the coastal harbours in Belgium: MOBAG 2000." WODCON XVI, Vol. 32, Kuala Lumpur, Malaysia.

Whillock, A. and Thorn, M. (1973). "Air Entrainment in Dropshafts.

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