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Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes cannot exceed six manuscript pages and three figures; a page of text may be substituted for a figure and vice versa. After informal review by the editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

Vane-Type Suppressor to Prevent Vortexing During Draining from Cylindrical Tanks

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Nomenclature

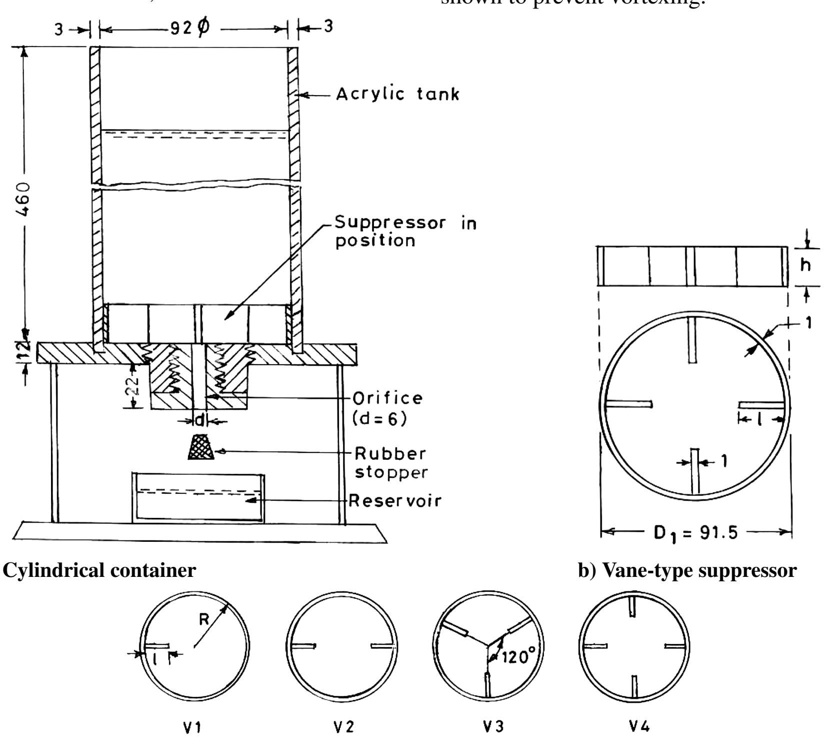
D = diameter of the container, mm
D_1 = base diameter of the suppressor, mm
d = diameter of the drain port, mm
H_c = critical height of liquid, mm
H_i = initial height of liquid, mm
h = height of the suppressor ring, mm
l = length of the vane, mm
R = radius of the suppressor ring, mm
t = time of emptying with rotation, s
t_0 = time of emptying without rotation, s

Introduction

WHEN liquid drains from a cylindrical tank through a axisymmetrically placed drain port, a vortex with an air core forms when the liquid level reaches a critical height H_c. The air core extends up to and reduces the effective cross-sectional area of the drain outlet.[1–4] The presence of initial rotation can augment the vortex formation, and the flow rate through the port can be[1] further affected. This phenomenon has practical relevance in the fuel feed system in space vehicles and rockets. Because of environmental disturbances, rotational motion can be generated in the liquid-propellant tank, which in turn can affect the rate of outflow to the engines.

Attempts have been made to suppress vortexing using different methods. Baffles were used by Abramson et al.[1] to suppress sloshing, which also prevented vortexing. Ramamurti and Tharakan[4] used stepped drain port to arrest vortex formation even with initial rotation present in the liquid column. Gowda[5] has shown that vortexing can be avoided by using tanks of square and rectangular cross sections. Furthermore, Gowda et al.[6] used a dish-type suppressor to prevent vortexing.

In the present study, a vane-type suppressor is suggested that effectively prevents vortex formation even with initial rotation given to the liquid column. Suppressors with varying number of vanes are shown to prevent vortexing.



a) Cylindrical container
b) Vane-type suppressor
c) Different vane-type suppressors

Fig. 1 Experimental arrangement.

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Experimental Arrangement

The arrangement is essentially the same as that used by Gowda et al.[6] and is shown in Fig. 1, where all dimensions are in millimeters. An acrylic tank with a i.d. of 92 mm and height of 460 mm with a drain hole of 6-mm diam centrally located at the bottom is used. Rotation is imparted to the liquid (water) in the container by controlled stirring (with the drain port closed by a rubber stopper; Fig. 1a), using varying number of revolutions of the stirrer over a constant period of time.[5] After the rotation, the rubber stopper is removed and draining started.

The vane-type suppressor is a circular ring made of aluminum and is 91.5 mm in diameter so that it fits comfortably within the tank and is located at the bottom of the tank (Figs. 1a and 1b). Varying numbers of vanes (1–4) are used (Fig. 1c), and they are designated V1, V2, V3, and V4. For each type of vane, the dimensions are $h = 8$ mm, $D_1 = 91.5$ mm, $R = D_1/2$, and $h/D_1 = 0.087$. In each case, the length l of the vane is varied as 40, 35, 30, 25, 20, 15, and 10 mm to study the effectiveness in suppressing the vortex. The $1/D$ was 0.89, 0.78, 0.67, 0.56, 0.44, 0.33, and 0.22. In most of the experiments, the height of the circular ring used is 8 mm. This was arrived at after conducting experiments with different ring heights, and the results pertaining to these are also given. In all of the experiments, 94 rpm is used for imparting the initial rotation to the liquid in the container. This is the same speed used for the experiments with the dish-type suppressor in Ref. 6. The initial height of the water H_i in the tank was 300 mm for all of the experiments, again as used in Ref. 6.

Results

All of the results are obtained at 94 rpm (a typical value around which the critical height H_c does not vary with speed[5]) with $D/d = 92/6$ and $h = 8$ mm or $h/D_1 = 0.087$ (Fig. 1c). The parameter used to assess the effectiveness of the suppressor is the ratio t/t_0, where t is the time of draining with rotation and t_0 the time of draining without rotation of the liquid in the tank. In Fig. 2, this shown vs l/R, the length ratio of the vane length l with $R = D_1/2$ (Fig. 1c). To accommodate the results for all of the vane configurations, that is, V1–V4, the coordinates on the ordinate in Fig. 2 are shown staggered.

It is seen from Fig. 2 that all of the vane configurations (V1–V4) are effective in suppressing the vortex, which is indicated by the value of t/t_0 approaching and becoming equal to 1. However, the value of l/R at which the vortex is completely suppressed and t/t_0 becomes 1 depends on the number of vanes. For example, with a single vane (V1), a much longer vane length is required ($l/R = 0.8$), whereas with three vanes (V3), a shorter vane length ($l/R = 0.55$) is sufficient to prevent vortexing.

As mentioned earlier, the height of the vanes h used is 8 mm ($h/D_1 = 0.087$) for the results shown in Fig. 2. This value was arrived at after conducting experiments with varying height h and determining its influence. Experiments were done for V4, and the results are given in Fig. 3. It is seen that for $l/2R > 0.08$, the value of t/t_0 reaches unity, that is, the vortex is completely suppressed.

The possible physical explanation for the effectiveness of the vane-type suppressor suggested is essentially the same as that for the dish-type suppressor.[6] The device appears to act as a roughness device and prevent the generation of low pressure at the center, that is, near the drain port. This possibly stops the dip formed at the liquid surface in the tank with rotation and draining started, to extend to the port; the vortex formation and the accompanying aircore is, thus, suppressed.

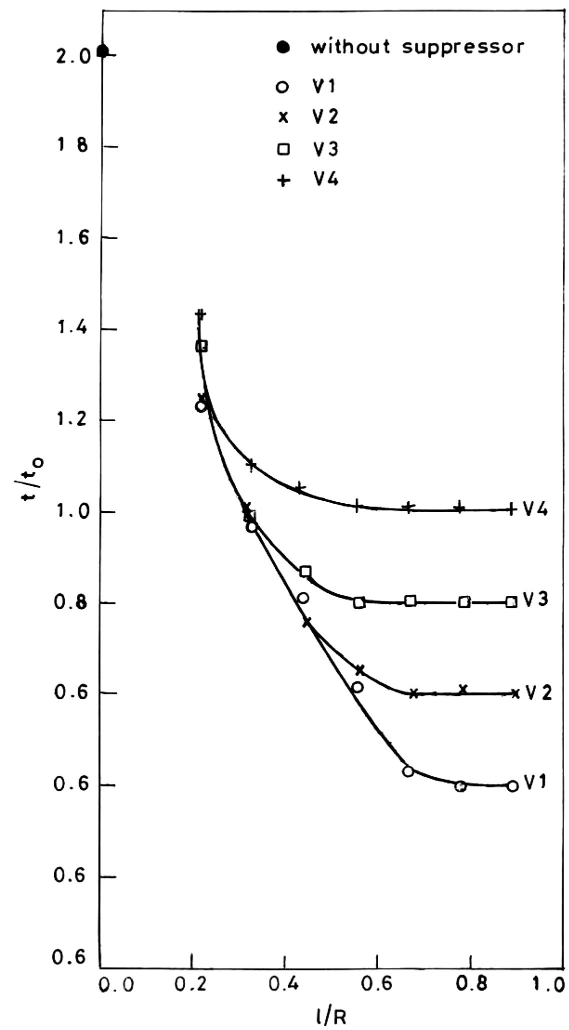

Fig. 2 Influence of number of vanes.

Conclusions

A very simple vane-type device is suggested to suppress vortexing during draining from cylindrical containers with circular cross section. The device is shown to be effective with a varying number of vanes. The length of the vane(s) for complete suppression of the vortex depends on the number of vanes. The device is very economical and simple to make for practical applications.

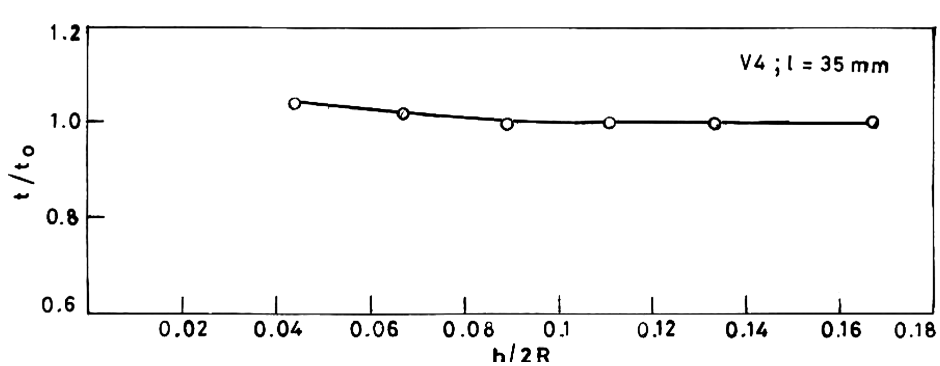

Fig. 3 Effect of relative height of vane (V4).

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