Effect of aqueous solutions of Carboxymethyl Cellulose on draining time in gravity driven flow

Ch. Vara Prasad, Ch. V. Subbarao King, P

Abstract: ***The time for gravity draining of water from a large Cylindrical open tank by means of a drain pipe (Located at the center of the bottom of the storage tank) is measured experimentally for the case of turbulent flow conditions in the drain pipe. Further, to reduce draining time, experiments are also conducted by the addition of water soluble Carboxymethyl Cellulose (CMC). The concentrations of CMC considered are 0.625,1.25, 2.5 and 5ppm respectively. The optimum concentration of CMC is found to be 0.625 ppm. Further, the re-usability of CMC polymer solutions is also contemplated and it is noted that there is an increase in draining time upon re-use of the CMC polymer solutions.***

Key Words: ***Draining time, Cylindrical tank, CMC polymer, re-usability, exit pipe***

I. INTRODUCTION

Process plants use different shapes and sizes of containers. The time required to empty the liquid from theses containers is known as efflux time or draining time [1].This time is important either for enhancing the production in many process industries [2].When a storage tank of large diameter is to be emptied through a drain pipe, laminar flow prevails in the storage tank. The flow conditions in the drain pipe depends upon the physical properties of the liquid and diameter of drain pipe. While the liquid drains from the tank, the flow changes from laminar in the tank to turbulent, there is drag, which increases the draining time. The drag need to be reduced by the addition of polymers and surfactants which are categorized under active means of drag reduction. However, polymers are better suited to surfactants because, to reduce draining time to the same extent, the concentration of polymers is less than that of surfactants. Most of the work reported in the literature include use of flexible polymers as drag reducing agents [3,4,]. CMC solution has been used for studies on drag reduction for closed systems in the concentration range of 200- 500 ppm [5]. However, the work reported in the literature for drag reduction using rod like polymers in once through system is sparse. The objective of the present work is to find the extent of drag reduction using CMC polymer where the flow is driven by gravity. The reduction is draining time is indicative of reduction in drag. The polymer used in this study is Carboxy Methyl Cellulose (CMC). Optimum concentration of CMC polymer which gives the least efflux time is arrived at. % Drag reduction for once through system is defined in the literature [6] as

$$\%DR = 100 * \left(1 - \frac{t_P}{t_W}\right) \qquad (1)$$

Where t_P is draining time with CMC solutions and t_W is draining time for water. The % Drag reduction when the liquid from a given initial height to specified final height is also measured.

II. EXPERIMENTAL PROCEDURES

2.1 Description of apparatus:

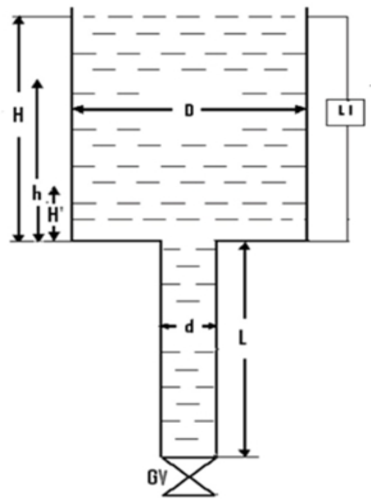

Figure 1: Open Cylindrical tank along with drain pipe

The apparatus used for carrying out the draining time experiments is schematically represented in Figure 1. The equipment used for experimentation consisted of known diameter open storage vessel rigidly placed on a structure. Carbon Steel pipe of diameter (d) is used as drain pipe and this drain pipe is directly welded to the storage vessel. The liquid from the tank is drained by means of a valve (GV) provided at the bottom most point of the drain t pipe. The level in the tank can be read from a transparent plastic tube attached to the tank.

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2.2 Efflux time measurement for single exit pipe:

The experiments are conducted using an open tank of 0.38m diameter and exit pipe of 4*10-3m. The length of exit pipe is 0.9m. Accurate measurement of diameter of exit pipe is carried out using Vernier Calipers. Efflux time measurements are also carried out by using a stop watch of 10miil seconds accuracy. Before performing the experiments, the tank and drain pipe are closed by the valve provided. The tank and the exit pipe are filled with water up to desired level. As soon as the valve is opened, the stop watch is also started. The time required for draining from a given initial height of liquid to final height of liquid is noted. The experimental draining time was designated as. The reproducibility of data is verified by repeating the experiments While preparing the aqueous solutions of CMC, known mass of CMC is dissolved in water to prepare a concentrated polymer solution. The solution is allowed to hydrate for one day. After one day, the concentrated solution is suitably diluted to obtain the desired concentration and efflux time measurements using CMC solution are carried out on similar lines mentioned above for water. The efflux time measured using polymer solutions is designated as.

III. RESULTS AND DISCUSSION :

The flow in the tank is laminar due to its large diameter of vessel compared to the diameter of drain pipe. The Reynolds number in the drain pipe is calculated as

$$\mathrm{Re} = \frac{dV_{2\exp}\rho}{\mu} \qquad (2)$$

Where Re is Reynolds number, d is the diameter of drain pipe, ρ and μ are density and viscosity of water respectively. $V2\exp$ is experimental velocity measured by

$$V_{2\exp} = \frac{D^2(H - H')}{d^2 t_W} \qquad (3)$$

Where is H initial height of liquid, H' ' is final height of liquid, is diameter of tank.

The Reynolds number is calculated and found to be turbulent only.

3.1 : Variation of draining time with concentration of CMC polymer solutions.

The variation of draining time in the absence and presence of aqueous Carboxy methyl cellulose solutions is shown below in Fig.2

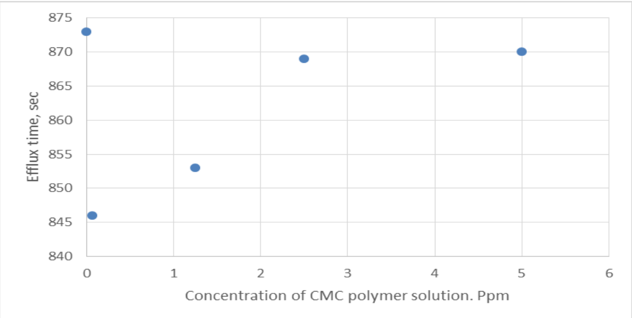

Fig.2: Variation of draining time with concentration of CMC

It can be seen from the plot that the draining time is less for all the concentrations of CMC solutions considered. Lower draining time is obtained when the CMC concentration is lowest. This is not in line with what is being reported in the literature for closed system [7]. This clearly suggests that optimum Polymer concentration depends upon whether the system is open system or closed system. Lowest draining time is obtained when the concentration of polymer is lowest, in this case it is 0.625 ppm. The Maximum drag reduction is obtained at 0.625 ppm concentration and this value is 4%.

Before draining of the Carboxy methyl cellulose solution from the tank, liquid level in the tank is maintained at 11cm.The cumulative %Drag reduction for drop in every 2 cm height is calculated. The variation of % Drag reduction with respect to cumulative level of liquid in the vessel is shown below.

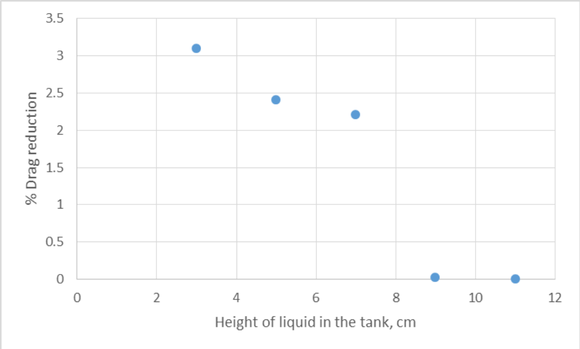

Fig.3: Variation of % Drag reduction with respect to level of liquid in the tank

The graph suggests that as the height of liquid in the tank is reduced, the % Drag reduction is increased. This is different when compared to flexible polymers like Poly acryl amide

The possibility of re-using the CMC solution is also explored in this studies. The following plot shows the variation of draining time with time (measured in no of days). The plot below shows the draining time variation with respect to no of days for 1.25 ppm CMC solution.

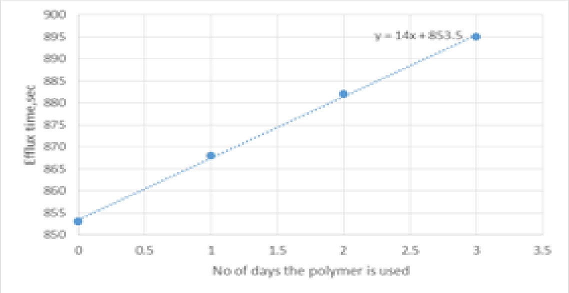

Fig.4: Variation of draining time vs no of days the CMC solution re-used.

The plot suggests that when the CMC solution used for drag reduction on the Zeroth day (Considering zeroth day as the day when polymer solutions are used for the 1st time) when re-used on the 1st day, there is an increase in draining time suggesting decreased drag reduction upon re-use. When the same solutions were used on the second, day, the % drag reduction is –ve (i.e increased draining time) and draining time was more than that of water.

This clearly suggests that only freshly prepared polymer solutions are to be used for conducing drag reduction experiments in once through systems.

IV. CONCLUSIONS

Some of the conclusions of the above study are

1. Optimum concentration of polymer solution is found to be 0.0625 ppm. In the concentration range considered, for all the concentration of polymer solutions, the draining time is less than that of water.This clearly suggests that rigid polymers like CMC also remain neutral or drag reducing when the flow in the exit pipe line is turbulent. This conclusion is different from what has been reported in the literature for rigid like polymers [8]. The % Drag reduction however is less than that of Poly acryl amide (PAM) flexible polymer in once through systems [6].
2. When a liquid is drained from a given height, % drag increased as more and more of liquid is drained from the tank.
3. For each experiment, freshly prepared aqueous CMC polymer solutions only will have to be used.

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