Modern Applied Science
www.ccsenet.org/mas
Vol. 4, No. 3
March 2010

Studies on Some Aspects of Jet Mixers I: Hydrodynamics

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Abstract

Mixing is one of the common unit operation employed in chemical industries. Conventional mixers are equipped with impellers but are expensive for mixing in large storage tanks and underground tanks. Jet mixers have become an alternative to impellers for over five decades in the process industry. For the design of jet mixers, the detailed hydrodynamics of the mixing process is not properly understood. In the present paper, hydrodynamic techniques are used to simulate jet mixing in a cylindrical tank. For this purpose, experiments were carried out to study the effects of various parameters such as nozzle diameter, jet position and jet velocity on mixing time. Results show that, for a given geometric arrangement, jet diameter is significantly more important in determining hydrodynamic characteristics of jet mixer. The results obtained give a good understanding of hydrodynamic aspects of mixing process in jet mixed tanks.

Keywords: Jet mixing, liquid hold up, Flow rate, Mixing time, Jet diameter, Jet position

1. Introduction

Mixing is one of the common unit operations employed in chemical industries. Mixing is usually carried out in order to produce a uniform mixture and it can be achieved using mechanical mixers, fluid jet mixers, static mixer or pipe line with tees. It can be used for a variety of purposes. Examples, homogenization of physical properties and composition prevention of stratification or deposition of suspended particles, for and improved rates of heat, mass transfer and chemical reaction. Examples of mixing operations include dissolution, leaching gas, absorption, crystallization and liquid-liquid extraction. Depending on the specific application and process mixing may be done in batch wise or in continuous mode and the content may be stirred either by rotating turbines and propellers or by jets of liquid. Impellers are the conventional devices used for mixing in industries. But they are very expensive for large storage tanks and underground tanks. Jet mixers have become an alternative to impellers for over 50 years in the process industry. In jet mixing; a part of the liquid in the tank is drawn through a pump and returned as a high velocity jet through a nozzle into the tank. This jet entrains some of the surrounding liquid and creates a circulation pattern with in the vessel thus leading to mixing of the content. In jet mixers, a fast moving jet stream of liquid is injected into a slow moving or stationary bulk liquid. The relative velocity between the jet and the bulk liquid creates a turbulent mixing layer at the jet flow, entraining and mixing the jet liquid with the bulk liquid. Jet mixers have several advantages over conventional impellers. It has no moving parts as in conventional agitators, there by reducing maintenance costs, and it is easy to install when compared with impellers. Agitators require support at the top of the tank, implying a pre-requisite for thicker walls of stronger materials. Mechanical agitators show disadvantages at an industrial scale with regard to investment and energy costs, and also sterilization and maintenance in biochemical processes and jet mixers are preferable in such situations. Jet mixers are used for the following applications. Hoffman, P.D. (1996) blending the inhibitor into the monomer storage tank to stop violent runway exothermic polymerization reactions Fonad, C. (1993) Bio- chemical applications. Jet mixers are more appropriate for mixing processes involving chemically sensitive liquids, Rice, P. (1981) Preparation of food stuffs. The hydrodynamic characteristics of jet mixer were studied by varying nozzle diameter, jet position and fluid properties. For this purpose, the experiments were conducted in 0.5m diameter, 0.6m height column. Five different nozzles have been employed and it is optimized based on the holdup characteristics. In order to study the effect of viscosity non Newtonian fluid such as Carboxyl Methyl Cellulose (CMC), Guargum was employed.

2. Literature Review

Considerable literature and measurements on jet mixing in tanks are available. Habib, D. Z. (2006) Numerical simulation of mixing in a large horizontal cylindrical tank has shown that blending time is a function of the flow pattern generated inside the tank by the jet. Consequently the jet location is very important in determining the blending time, not so much due to its length but mainly due to the patterns of flow it creates inside the tank. A significant reduction in the values of blending time was obtained as a result of relocating the jet out let which resulted in better flow patterns inside the tank. Jayanthi, S. (2001) to find optimum shape of tank for better mixing found that conical bottom is better than hemispherical ellipsoidal, flat bottom for mixing and deeper study of the underlying hydrodynamics such as the effect of tracer diffusivity, Reynolds number, height to diameter ratio, multiple jets. VijaySarathi, J. (2008) predicted parametric Sensitivity analysis where in the effects of tank parameters. The parameters investigated were jet velocity, jet angle, location of jet, effect of hear source and tank height to diameter ratio. Kalachelvi, P. (2007) conducted experiments by varying parameters like jet diameter, jet position and jet inclination to find their effects on mixing time. The optimum angle is found to be an injection angle of 30^0 for jet located either at two-third of the volume of the tank or top and bottom of the tank, which gives the shortest mixing time. This optimum angle is not universal and varies with the location of the jet inlet. T.Maruyama, *et al.* (1986) to investigate systematically the effect of several geometric parametric in jet mixing in tanks using horizontal, inclined and vertical jets. They proposed that the mixing time is a function of Reynolds Number and of the largest free jet length, but also emphasized the role of the flow patterns existing inside the mixing tank on the mixing time behavior. Patwardhan, A.W. (2002) predicted mixing behavior in jet mixed tanks, mixing time and concentration profiles have been compared with the experimental measurements over a wide range of jet velocities, Nozzle angles and Nozzle diameters. Rande, V.V. (1996) predicted results of the mixing time agree with published experimental data for different jet configuration. Rakib, M.A. (2002) presented a model of Jet Mixing and validated their numerical model against the experimental results.

3. Experimental

The experimental setup is shown in Figure1. It consists of a cylindrical borosilicate glass tank of 0.5m diameter and 0.6m height in which a nozzle is installed at the centre of the tank. A pump is used to maintain a recycling condition which withdraw fluid from the storage tank and deliver it through the nozzle where the fluid is ejected to the mixing tank as a jet stream. The photographic view of experiment set up shown in the Figure 2 and the different types of nozzles are shown in Figure 3.The design details, process fluids and other parameters pertaining to jet mixer is shown in Table 1. The inlet flow rate is measured by precalibrated rotameter (35-350liter per minute) and (10-100liter per minute) respectively. The nozzle specifications and position of the nozzle are shown in Table 2 and Table 3 respectively. The fluid from storage tank is pumped in to the mixing tank through a nozzle; the output flow rate is adjusted to maintain the initial liquid holdup. After attaining the steady state the initial hold up is noted. The inlet flow rate is varied then the corresponding variations in the liquid holdup and pressure difference are noted. The effect of jet position on mixing pattern is studied by changing the clearance between the nozzle and the bottom of the mixing tank. The effect of geometrical properties on holdup is studied by changing the various diameters of nozzle and the same experimental procedure is followed.

4. Result and Discussions

4.1 Effect of Nozzle

The effect of nozzle design was studied for jet mixer having diameter (T) of 0.5m and height (H) of 0.6mm. For this purpose five different nozzles were designed and tested in the above column. In order to compare the effectiveness of the nozzle the end effect was compared based on the active area. The effect of nozzle design was compared for three different positions to ensure the reproducibility of the result. The effect of liquid flow rate on liquid holdup for different jet position was shown in Figures 4-6. From these graph it can be seen that nozzle design having 20 % active area shows more holdup than the remaining nozzle deign. The holdup was found to decrease if the active area exceeds 20%. The holdup increases with an increase in flow rate this is due to the dependence of flow rate with the dispersed phase. On the other hand, the continuity of the dispersions process altered when the active area exceeds 15%.The travelling path of the flow was disturbed and there is formation of secondary loop which result in decrease in holdup. The effect was compared for three jet position. The same result was observed irrespective of the jet position.

4.2 Effect of Jet Position

The effect of jet was also studied for all the nozzle design. The comparison of various nozzles and their position result was given in Figure 4-6. From these graphs it can be seen that jet position of T/1.8 shows more hold up than T/2.3 and T/1.6. When the jet was located at the centre of the vessel the flow path generated by the jet nozzles will not get disturbed it takes complete radial direction and then follow axial direction and hence a complete loop was resulted. This was not happening when jet position was less or greater than the diameter of the tank.

4.3 Effect of viscosity

The effect of viscosity was carried out for the optimized nozzle design and nozzle location. In order to study the effect of viscosity test fluid namely carboxyl methyl cellulose and gaur gum were used. The concentrations of test fluid were varied in the range of 0.2 to 0.5 % (volume %). The effect of flow rate on holdup for different test fluid and various concentrations is shown in Figure 7-9. From these figures it can be seen that the holdup decrease as concentration of fluid increases. This may be due to jet velocity has to increase to retain the specified holdup. Also the flow path and circulation path is minimized when concentration of fluid is increased with respect to water.

5. Conclusion

Jet mixers can be suitably replaced in place of conventional mixers for large tanks. Among the nozzle design studied nozzle with active area of 20 % shown more holdups with less power consumption. Jet position (from bottom of the vessel) of T/1.8 shows more hold up. The power consumption increase with increase in concentration of the fluid.

Nomenclatures

C_1 = Position of nozzle, m

C_2 = Position of nozzle, m

C_3 = Position of nozzle, m

g = Acceleration due to gravity, m/s^2

H = Column height, m

h = Liquid height, m

i.d = Internal diameter of column, m

lpm = Liters per minute

N_1 = Nozzle 1

N_2 = Nozzle 2

N_3 = Nozzle 3

N_4 = Nozzle 4

N_5 = Nozzle 5

Q = Flow rate, m^3/s

T = Diameter of the column, m

T/1.6 = Jet position, m

T/1.8 = Jet position, m

T/2.3 = Jet position, m

References

Habib, D.Z. (2006). Numerical Simulation of Mixing in a Jet Agitated Horizontal Cylindrical Tank: *International Journal of Computational Fluid Dynamics* “Vol. 20.” Number 2, pp 127-136.

Hoffman, P. D. (1996). Mixing in a Large Storage Tank: AICHE Symposium Series: Number 286/88/77-82.

Jayanti, S. (2001). Hydrodynamics of Jet Mixing in Vessels: *Chemical Engineering Science* 56:193-210.

Kailas, L. Wasewar., & VijaySarathi, J. (2008). CFD Modelling and Simulation of Jet Mixed Tanks: *Engineering Application of Computational Fluid Mechanics*" Vol. 2". Number 2, pp. 155-171.

Kalaichelvi, P. (2007). Mixing Time Estimation and Analysis in a Jet Mixer: *ARPN Journal of Engineering and Applied sciences* "Vol.2". Number 55, pp 35-43.

Lane, A.G.C., & Rice, P. (1981). An experimental investigation of jet mixing employing a vertical submerged jet: *International Chemical Engineering Symposium series* 64:K1.

Maruyama,T., Kamishima,N., & Mizushina,T. (1986). Jet Mixing of Fluid in Tanks: *Journal of Chemical Engineering of Japan* 17:120.

Maruyama,T., Kamishima,N., & Mizushina,T. (1986). Jet Mixing of Fuids in Vessels: *Encyclopaedia of Fluid Mechanics* "Vol. 2". Gulf Publishing Company, Houston, TX, pp. 544–562.

Patwardhan, A.W. (2002). CFD Modelling of Jet Mixed Tanks: *Chemical Engineering Science* 57:1307-1318.

Ranade,V.V. (1996). Towards better Mixing Protocols by designing spatially periodic Flows: The case of a jet mixer: *Chemical Engineering Division*, National Chemical Laboratory "Vol. 51". Number 11, pp. 2637-2642.

Simon, M., & Fond, C. (1993). Experimental Study of Mixing Performance using Steady and Unsteady state Jets: *Canadian Journal of Chemical Engineering* 71: 507-503.

Zughbi, H.D. & Rakib, M.A. (2002). Mixing in a Fluid Jet Agitated Tank: *Chemical Engineering Communication* 189:1038-1056.

Zughbi, H.D. & Rakib, M.A. (2002). Mixing in a Fluid Jet Agitated Tank: Effect of Jet angle and elevation and number of Jets: *Chemical Engineering Science* 59:829-842.

Table 1. Jet Mixer Specification

Column Diameter, (i.d) (T)	0.5m
Column Height, (H)	0.6m
CMC Solution	0.2%, 0.3%, 0.5% (v/v %)
Gargum	0.2%,0.3% (v/v %)
Glycerol	0.5% (v/v %)
Rotameter	10-100 (lpm) 35-350 (lpm)

Table 2. Nozzle Specification

Nozzle	Active area (%)
N_1	53.2
N_2	29.8
N_3	20.3
N_4	11.4
N_5	14.7

Table 3. Position of the Nozzle

Position 1	T/2.3
Position 2	T/1.8
Position 3	T/1.6

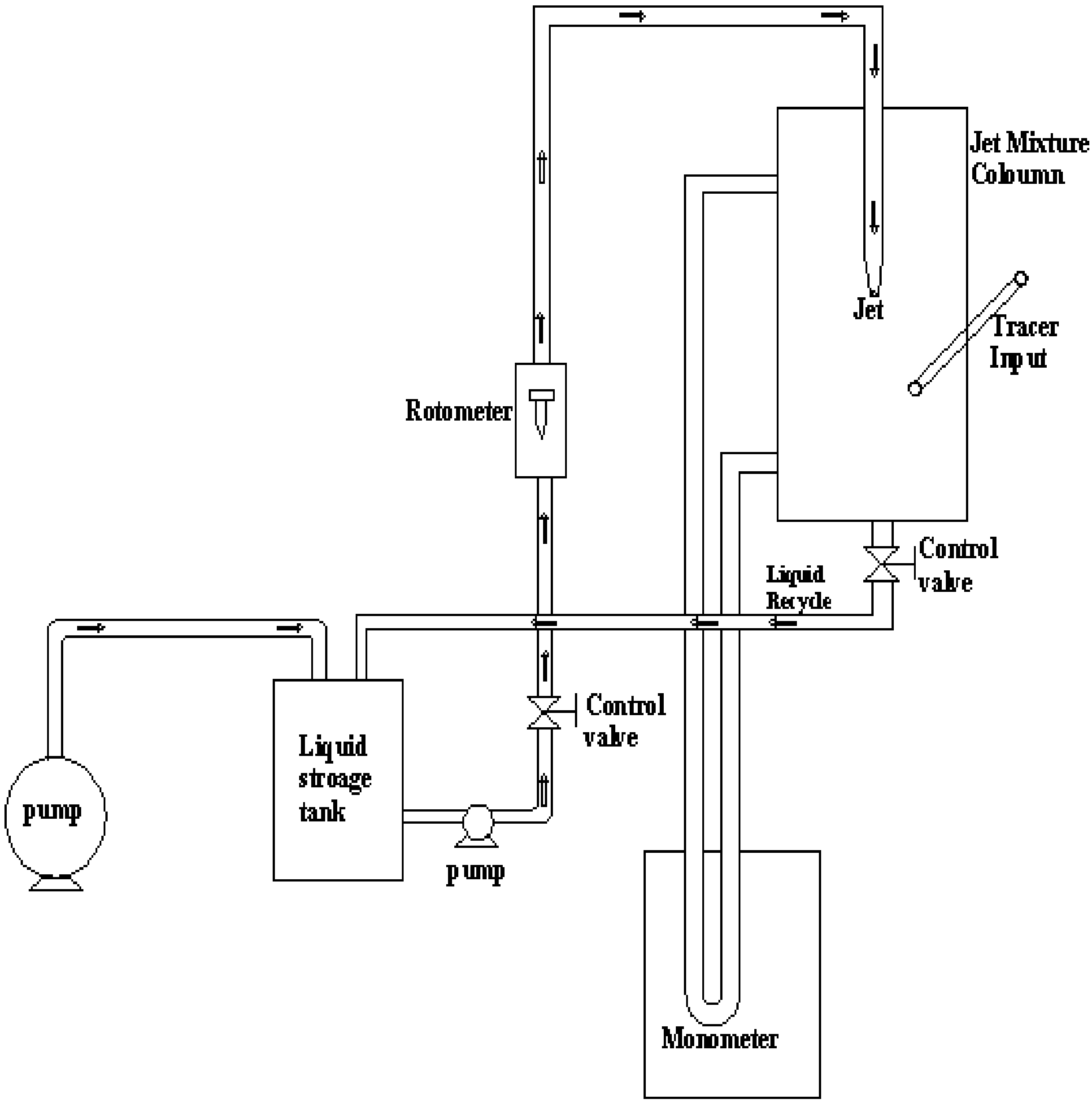
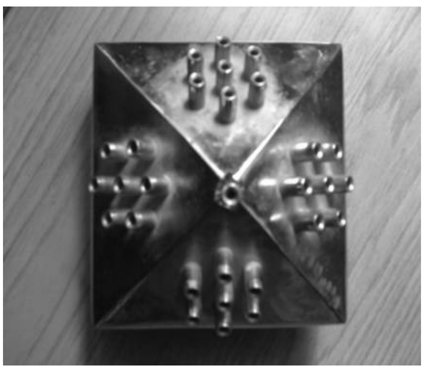


Figure 1. Experimental Set up

Figure 2. Project Equipment



Nozzle N_1

Nozzle N_2

Nozzle N_3

Nozzle N_4

Nozzle N_5

Figure 3. Types of Nozzles

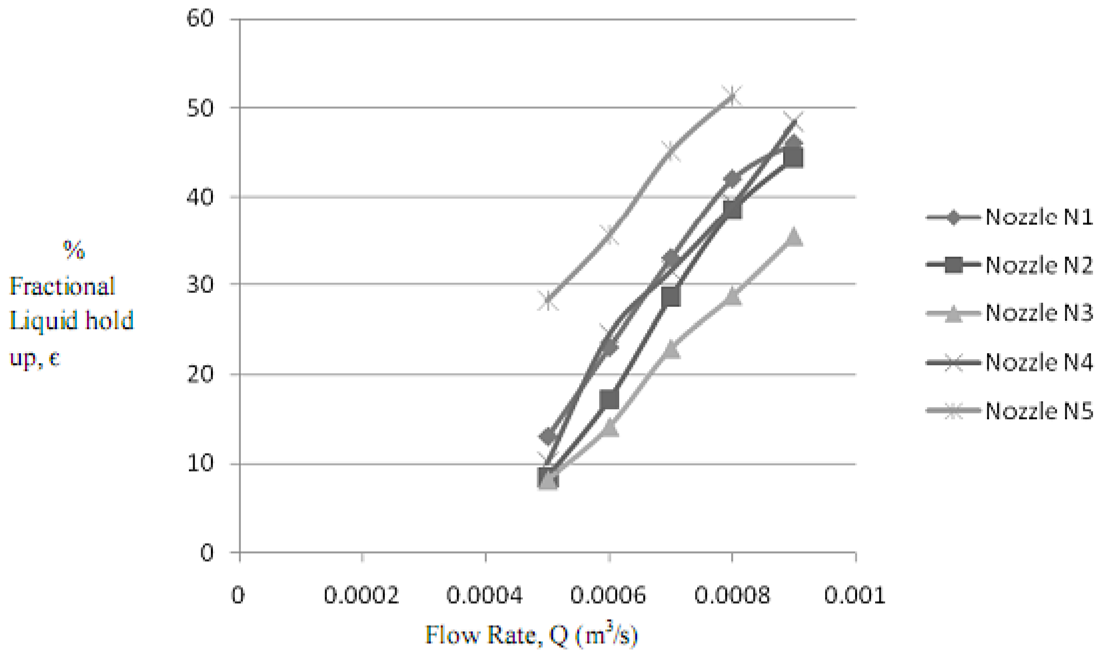


Figure 4. Comparison of various Nozzles and position for C_1= T/2.3

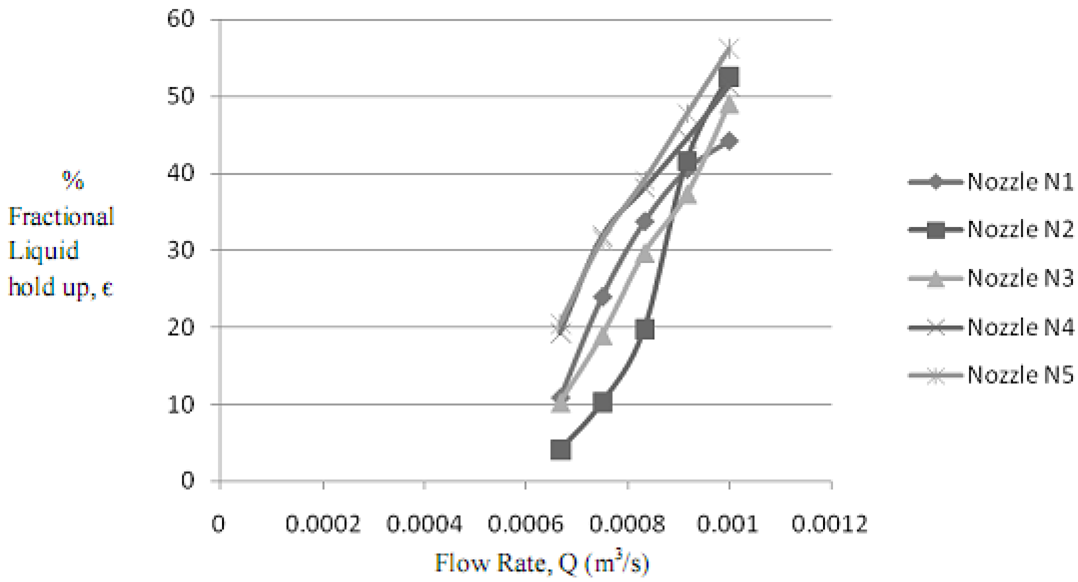


Figure 5. Comparison of various Nozzles and position for C_2= T/1.8

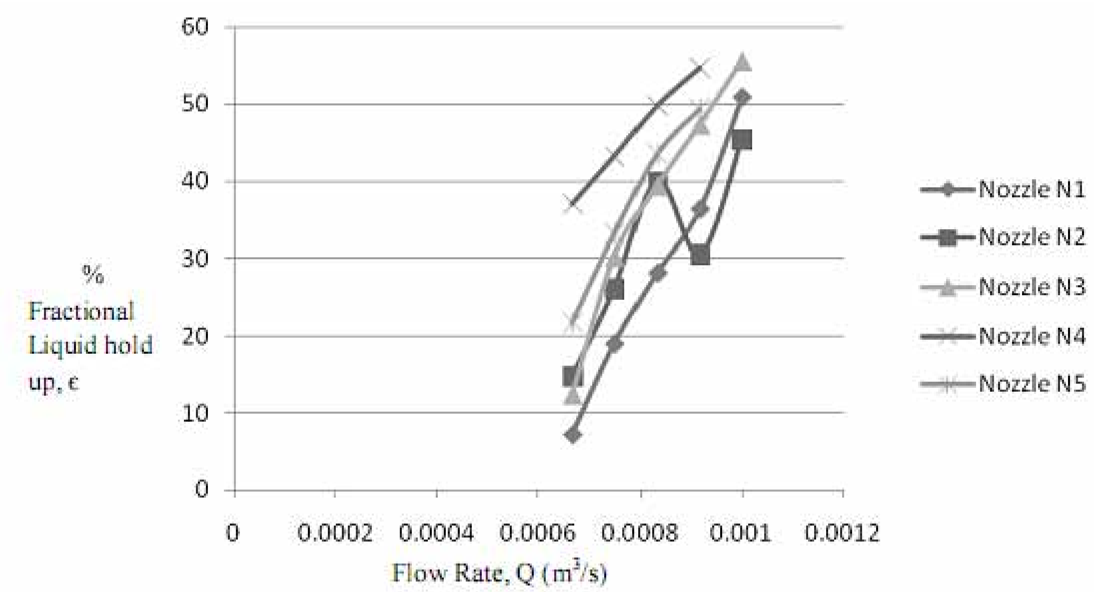


Figure 6. Comparison of various Nozzles and position for C_3= T/1.6

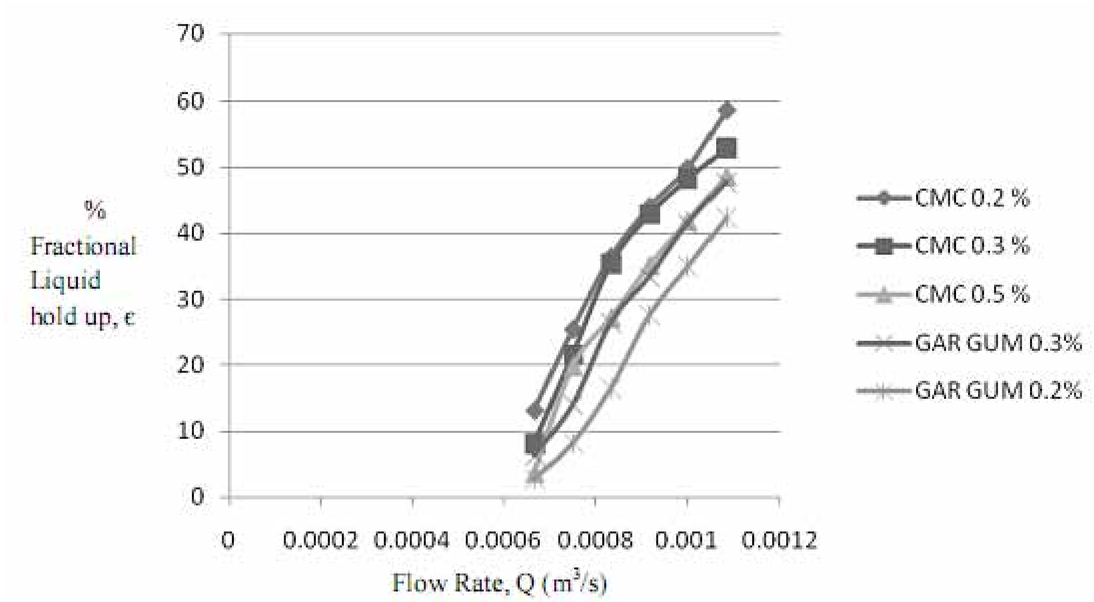


Figure 7. Effect of properties of fluids for nozzle N_3 at C_1= T/2.3

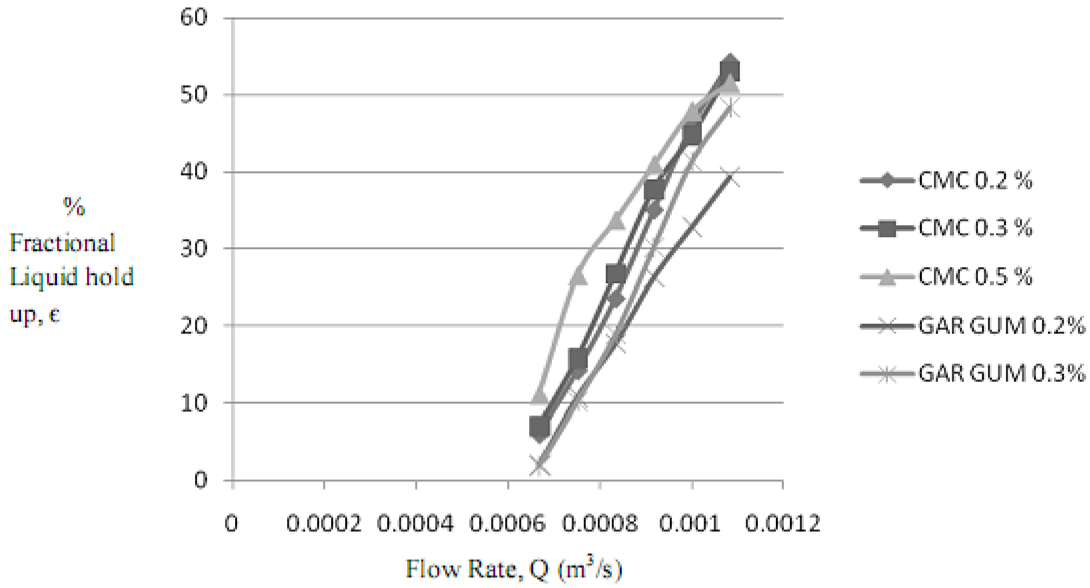


Figure 8. Effect of properties of fluids for nozzle N_3 at C_2= T/1.8

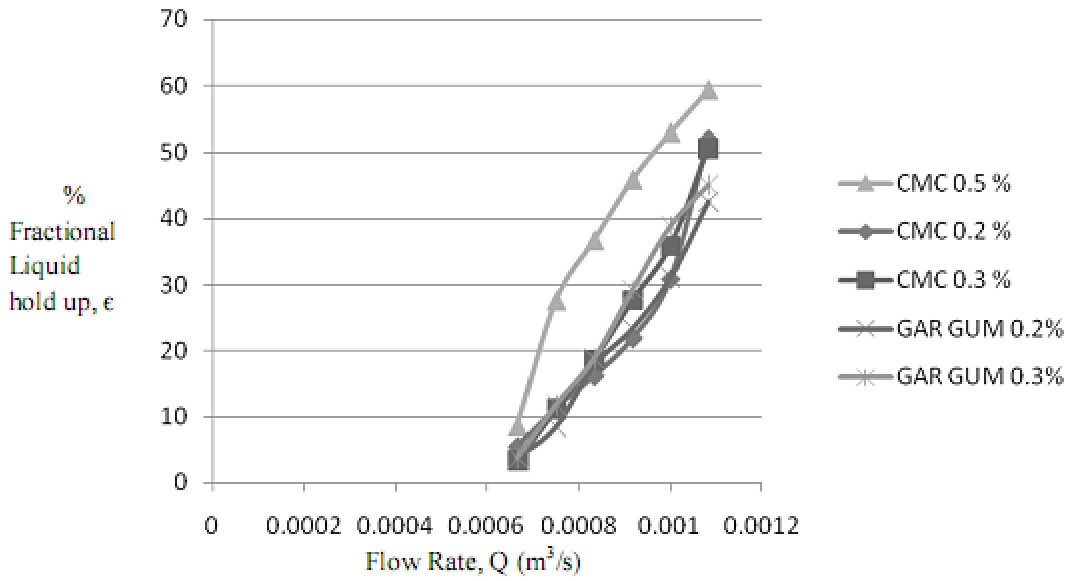


Figure 9. Effect of properties of fluids for nozzle N_3 at C_1= T/1.6