INVESTIGATIONS OF HIGH VELOCITY JET ONTO FLUIDIC PART

Zahid H. Khokhar

Messrs: ARIFA, RB West Canal Side, P-659/2420, St. Nineteen, Faisalabad, Pakistan.
Emails: hafeezzahid@hotmail.com; zahidhkhokhar@yahoo.com, P.E.,mIACSIT.
Corresponding email: zahedhk@gmail.com

ABSTRACT

Model system of one-many fluids contained in single container is under consideration introducing a high velocity jet at top location onto system of fluids. The mechanism is flow, hit, push, penetrate and replace. There are many actions which are observable and can be included into mechanism. In this work, with introducing high velocity jet, simulations are investigations. Blown jet flow is round enough. Surface of fluid changes its shape. The dip fizzy bubble for various velocity jets is shown. The influence is drawn between the surface dip generated and variation of jet velocity; within phase diffraction occurs. Mass transfer is noted. Fuzzy interfacing is performed to relate jet, continuum phase and absorption too. Such operations are incited to promote the excessive jet-fluid systems.

KEYWORDS

Jet, Mass transfer, Nanotechnology, Disk Reactor, Fragrance Industry, Low Temperature

INTRODUCTION

Synthesis of santalol is fragrance industry; sandalwood oil component: campholic aldehyde is used as an intermediate. Zink Chloride $ZnCl_2$ and $ZnBr_2$ Zink Bromide are used as catalysts. Extraction of these catalysts is difficult. Disk reactors are used for the film production on the surface. Its cleaning is needed when the catalyst is fixed on the surface. Disk may be spinning or not as required by the process conditions. The inlets and outlets of the spinning disk reactors are also need to be rinse heavily after such operation. Jet arrangements were investigated [1].

Computational fluid dynamics provide insight into the engineering aspects of the reacting and flowing mixtures as experimental verification. An abrupt variation of physical and transport properties is of great importance in manufacturing industry. The process of fluids bringing close to each other is important in the heating/cooling of reactants or to sup-press side reactions. A high penetration of fluid into other fluid has spreading into fluid pressing it. The release of which then may produce back flow which becomes important in case to control the process. These laboratory observations in pharmaceutical chemical production industry are.

The induction of water to the inlet air as a means of internal cooling [2] was reported. Transfer on top blowing liquid surfaces [3] and turbulent mass transfer in jet flow [4] were reported. Absorption and emission of high-pressure liquids and supercritical fluids were studied [5]. Observation of mixing [6] and an analogy of turbulent shear flow mixing and rapid chemical reactions [7] were reported. Comparison of single-point injection [8] was published. Mixing in pipeline with side-, opposed-, and multiple-tees [9] was investigated and mixing in pipeline with side-tee was reported [10] and presented [11].

Indus-trial designing of mass transfer intensification [12] and modeling of heat and mass transfer and absorption-condensation dust and gas cleaning in jet scrubbers were presented [13]. Experimental investigation on splashing and nonlinear fingerlike instability [14] was reported. Research on underwater rocket separation [15] was performed. Mass transfer with a jet directed at a two phase interface [16] was reported. Bubble size and mass transfer characteristics [17] and mass exchange in a jet vessel [18] were carried out. Bubble size is not much affected by size of nozzle. Structure of air jets into water [19] was studied. In present, jet size is constant and the velocity of jet is influencing on interface surface and fizzes the dip bubble size.

In this work, a jet of many jets was introduced at an able location to nozzle down into the system. System was empty, partially and fully filled with secondary fluid/s one by one. The jet enters into empty control volume. Its profile is drawn. The influences are shown between the surface dip generated of the fluid and variation of jet velocity when container is partially filled. The velocities of the jet introduced de-form the surface of the fluid contained in the system. On hitting fluid, it impacts the fluid, penetrates-displaces it, Velocity variation influenced the dip and other operations. Other flows types with each other during injection may further are included in the bowl scope. Then the control volume container system of carbonyl sulfide and water under air within partially filled is.

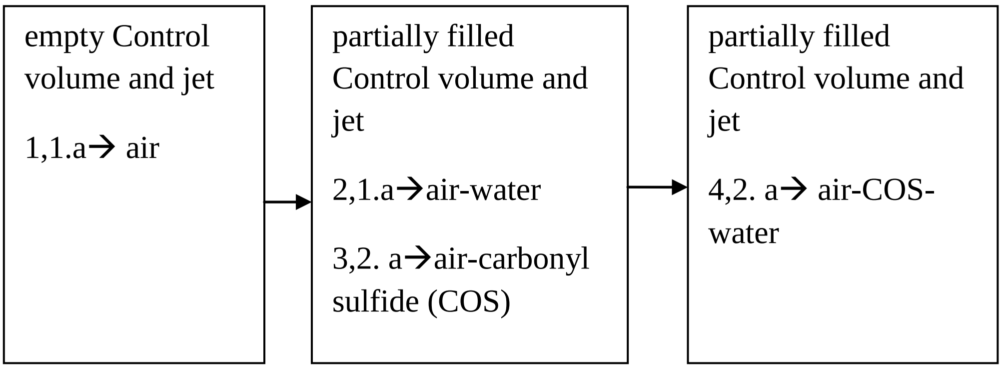

Figure 1: The arrangement of simulation cases

PROCEDURES

The arrangement of work performed is shown in figure 1. It shows the arrangements of jet and control volume fluids. The container was empty containing only air. Then the container was partially filled with water. Partially filled is such as the rest space is filled with air. Further, the container was half filled with the fluid gas which was carbonyl-sulfide, COS. The jet was of air. The f-j ratio is 2.073968. In further fourth case the container was considered as half filled with equally carbonyl sulfide and water. The geometry of L width two score and D depth half score was constructed. The ratio of horizontal L to vertical D Depth was L/D~2.5 [22]. Control volume was constructed, meshed, and refined at interests. Mesh was used of type structured quad pave. It was spaced axi-symmetric with steady time using viscous model. Computational fluid dynamic package was used to solve the system. It was segregated with standard k-epsilon turbulence. The standard k-ε model is a semi-empirical model based on model transport equations for the turbulent kinetic energy k and its dissipation rate ε. The model transport equation for k is derived from the exact equation, while the model transport equation for ε was obtained using physical reasoning. The kinetic energy, k, and its dissipation, ε, are obtained from the following transport equations:

$$\rho \frac{Dk}{Dt} = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right] + G_k + G_b - \rho\varepsilon - Y_M$$

$$\rho \frac{D\varepsilon}{Dt} = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial \varepsilon}{\partial x_i}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k + C_{3\varepsilon}G_b\right) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}$$

where, G_k represents the generation of turbulent kinetic energy due to the mean velocity gradients, G_b is the generation of turbulent kinetic energy due to buoyancy, Y_M represents the contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate, $C_{1\varepsilon}$, $C_{2\varepsilon}$, and $C_{3\varepsilon}$ are constants, σ_k and σ_ε are the turbulent Prandtl numbers for k and ε. D is substantial derivative and is given as.

$$\frac{D}{Dt} = \frac{\partial}{\partial t} + (v \cdot nabla),$$
$$where \rightarrow nabla = \delta_x \frac{\partial}{\partial x} + \delta_y \frac{\partial}{\partial y} + \delta_z \frac{\partial}{\partial z}$$

Vector v may be described by magnitudes of its projections and its analytical representation is

$$v = \delta_x v_x + \delta_y v_y + \delta_z v_z$$

Mixture multiphase model and VOF multiphase model each at a time were used. Unsteady turbulence multiphase modeling simulations were performed. Equation of continuity and equations of motions were resolved. In geometry, continuum was assigned air. Further, top and bottom of control volume were introduced as top: 0.5, Bottom: 0.5. Assigning air to top, water-liquid was assigned to bottom. In figure 1, this was used for system for step one and step two. The second geometry of depth two score, and width half score was constructed. Control volume was constructed, meshed, and refined at interests. Mesh was used of type structured quad pave. It was spaced axi-symmetric with steady time using viscous model. Fluent 6.2.16 was used to solve the system. It was segregated with standard k-epsilon turbulence. Temperature and pressure were atmospheric. Mixture multiphase model and VOF multiphase model each at a time were used. Unsteady turbulence multiphase modeling simulations were performed. Boundary conditions were assigned at continuum and inlet. No slip condition was applied on walls. Equation of continuity and equations of motions were resolved. Top and bottom of control volume were introduced as top: 0.5, Bottom: 0.5. Top was assigned air whereas bottom was assigned carbonyl sulphide. Further, top and bottom of control volume (CV) were introduced as top: 0.5, Bottom: 0.5. 50% of bottom was interlined with carbonyl-sulfide forming a system as air: COS: liquid-water ~ 0.5: 0.25: 0.25. Table 1 shows the fluidic space distribution within geometry for different control volumes. As jet was introduced at the top of the system at zero depth, it flowed to the surface of fluid and made a dip changing the volume fraction. The penetration of jet is a measure of dip and/or the displacement of the fluid. Upon hinting the both fluids gas spreads, absorbs and mixes. Total of four control volumes for two geometries were solved. Range of jet velocity variation for solving one control volume was 1 to 10. Properties with method and values used are listed in the table 1.

Table 1: Fluidic space distribution within CV geometry

CV \ Space	0.25	0.25	0.25	0.25
1	Air	Air	Air	Air
2	Air	Air	Water	Water
3	Air	Air	Carbonyl sulfide	Carbonyl sulfide
4	Air	Air	Carbonyl sulfide	Water

Table 2: Constant Properties of fluids

Fluid	Air		COS ,Carbonyl Sulfide	
Property	Units	Value	Units	Value
Density	kg/m^3	1.225	kg/m^3	2.548
Cp (Specific Heat)	j/kg-k	1006.43	j/kg-k	755
Thermal Conductivity	w/m-k	0.0242	w/m-k	0.0104
Viscosity	kg/m-s	1.79E-05	kg/m-s	1.20E-05
Molecular Weight	kg/kg mol	28.966	kg/kg mol	60.07455

RESULTS

Air jet was introduced from top. High velocity jet was distinguished from a range of jet velocities used. The jet velocity was varied from 0.01 to 1000 meter per seconds. At thirty eight the jet was considered much energetic for present system. At a ten unit interval the velocities were varied and selected six out of many cases were run. Figure 2 shows a steady jet into empty control volume. It is in left first box of figure 1. Air is getting into inlet. Jet is turning around and coming back. Splashing and fingerlike stability are investigated. The simulation run is showing splashing fingerlike flow [14]. It is dispersion of jet. Jet is clouding at top. These phenomena may be used to address many industry related problems of cleaning and scrubbing not only the container but another fluid too. Also these seen points may be explored for research on under-water rocket separation [15]. Few vectors are trying to come out from the way those were blown. The jet flow figure is round enough within the control volume.

In figure 3, the system was filled partially with water-liquid whereas the other half at top was air. The grid was meshed and refined as of interests. It profiles jet flow in air-water system. Velocity magnitude is plotted along position. At very entrance the jet is high velocity energetic. As long as it travels down within air space, it is becoming droopy near surface of fluid to hit it. The dip formation can be seen at the surface of water at interface position.

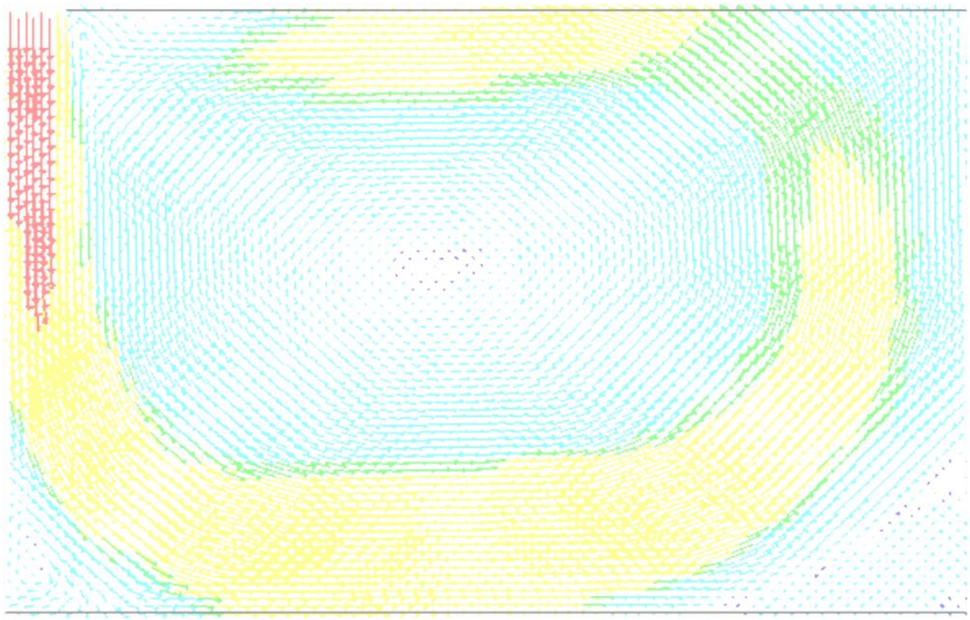

Figure 2: Jet Vector contours, Air entrance at left top side

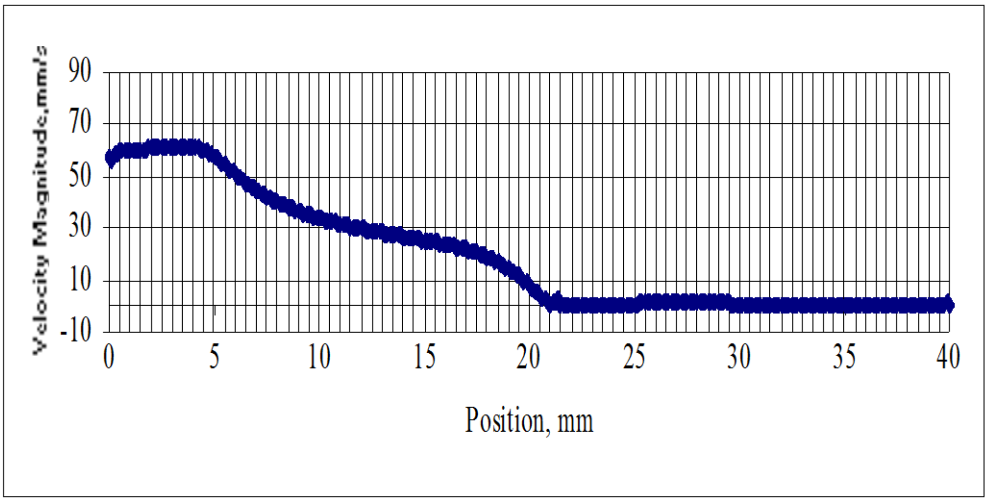

Figure 3: Profile, Air-water system, velocity magnitude is plotted along position.

Figure 4 shows air jet and half filled Carbonyl sulfide. The air contours highlight the dip formed at Carbonyl sulfide surface by hitting of air jet. Seeing the dip at interface, it can also be seen that gas is layering up by the hit of high velocity jet that is the splash jumping of fluidic gas can be seen. There are many ring formation on the other side of jet entrance. The penetration of jet is a measure of dip with the displacement of the fluid. For penetration of air and displacement of fluid, excellent measurements are obtained.

The difference of minima and maxima bubble data point cases 1,2,3,4,5,6 are shown in figure 5. The circle size of bubbles is corresponding difference. The 3 is a point where dip is increased. The force of jet rides the surface. The very bubble circle is bigger than the next few. The gas responded in return.

As velocity increases, the bubble circle is decreased but a change can be seen at higher velocity. Comparing the three velocities with next three higher velocities, it can be seen that the increase in dip depth is not linear.

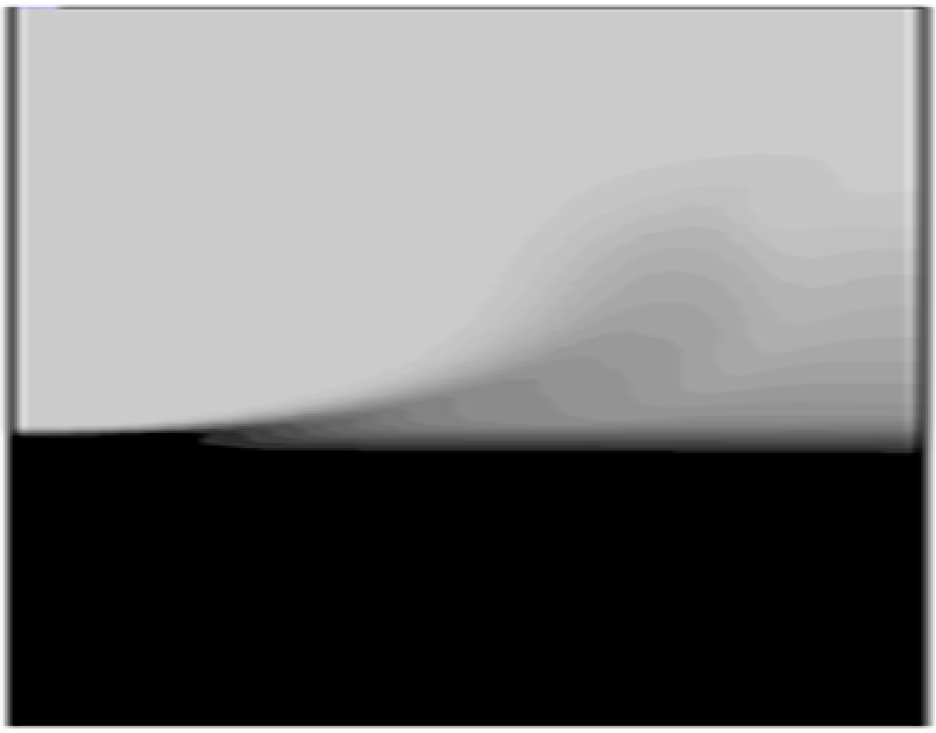

Figure 4: Dip fizzy layer formation. Air volume fraction contours

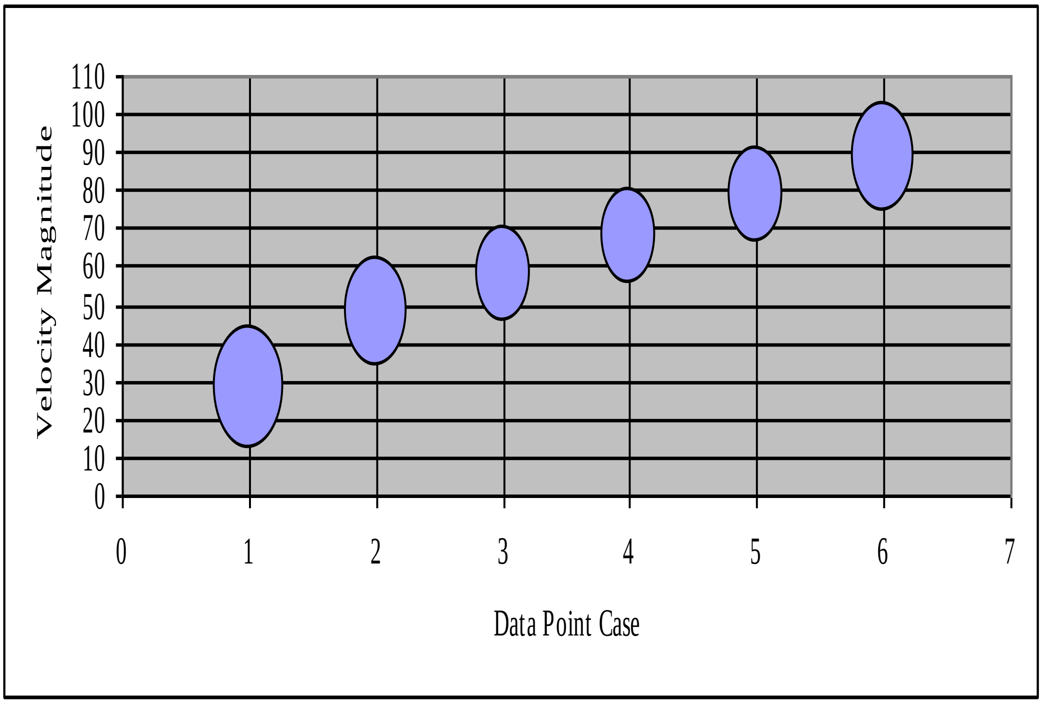

Figure 5: Difference of minima and maxima of dip relative to data point case 1,2,3,4,5,6 ~ velocities 38:10:88.

The linearity occurs during both sections. The point is between 3 and 4 and is near to 3 where the squeeze can be seen. This is the point where reactions may be controlled. Further system as given in figure 6 is considered partially filled with carbonyl sulfide and water equally onto each other. Jet disturbed the system and the carbonyl sulfide mixes into water for the jet.

Initially there was no fraction of gas other than in COS bands. Introduction of high velocity jet produced turbulence and mass transfer occurred. Absorption of gas happened. The gas mixed into water. The difference is the buffer zone of absorption process. Different jets showed different effects on the system.

The fractions of gas are shown as mass transfer bands. Due to jet driving gas has penetrated and transferred through the water. At least five distinguish parts are formed as shown in figure 7.

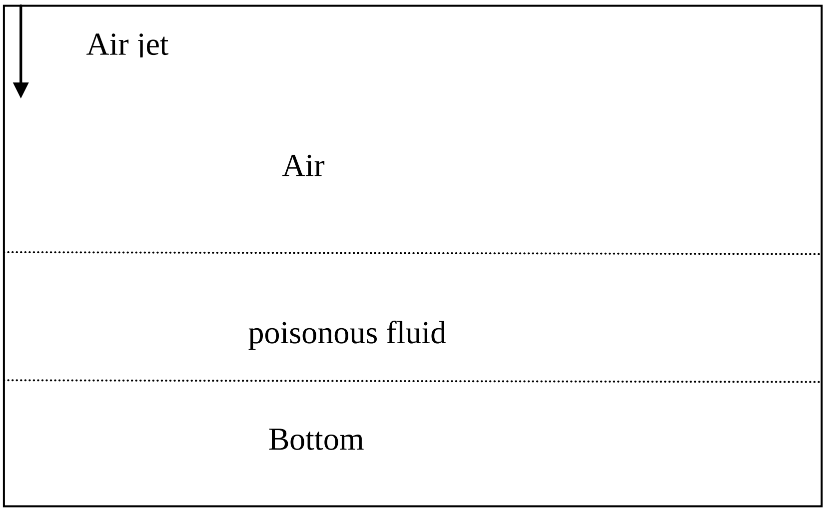

Figure 6: Air, unexpected gas and liquid water after downing of jet into control volume

The absorption is taking place to result into mass transfer and mixing. The phenomena are occurring at convenient level. Simply, the lines can be drawn of low and high concentration of gas within water region. With complex interrogation, further narrow down research may be performed to locate the relationship between high velocity jet and gas transfer within water.

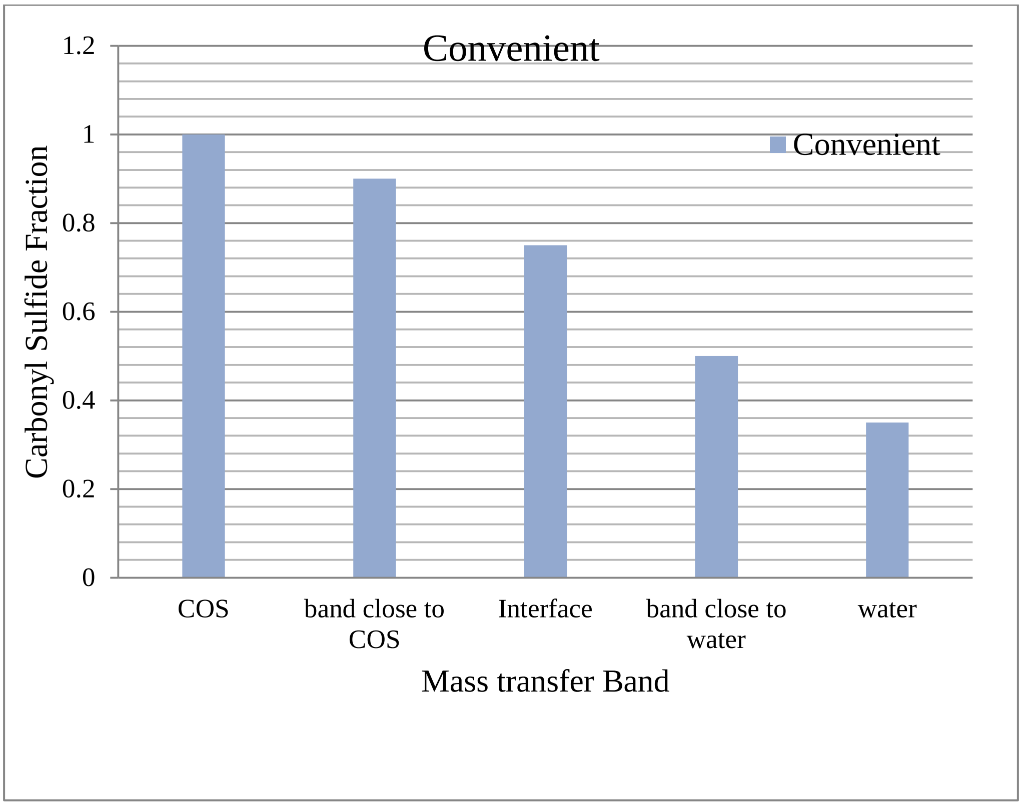

Figure 7: Mass transfer absorption of COS gas within water due to jet

Jet velocity and constituents of control volume are considered as inputs. Output is absorption. Fuzzy interfacing is constructed among the inputs and output. Knowledge representation in fuzzy logic [24] is published. Fuzzy work is performed by designing fuzzy interface system [23]. Absorption, velocity of jet and constituent phases of control volume is modeled by fuzzy interface system. Figure 8 shows the relationship among jet velocity, phases in the control volume and absorption of gas into bottom by jet. Absorption of gas into water is seen by high velocity jet.

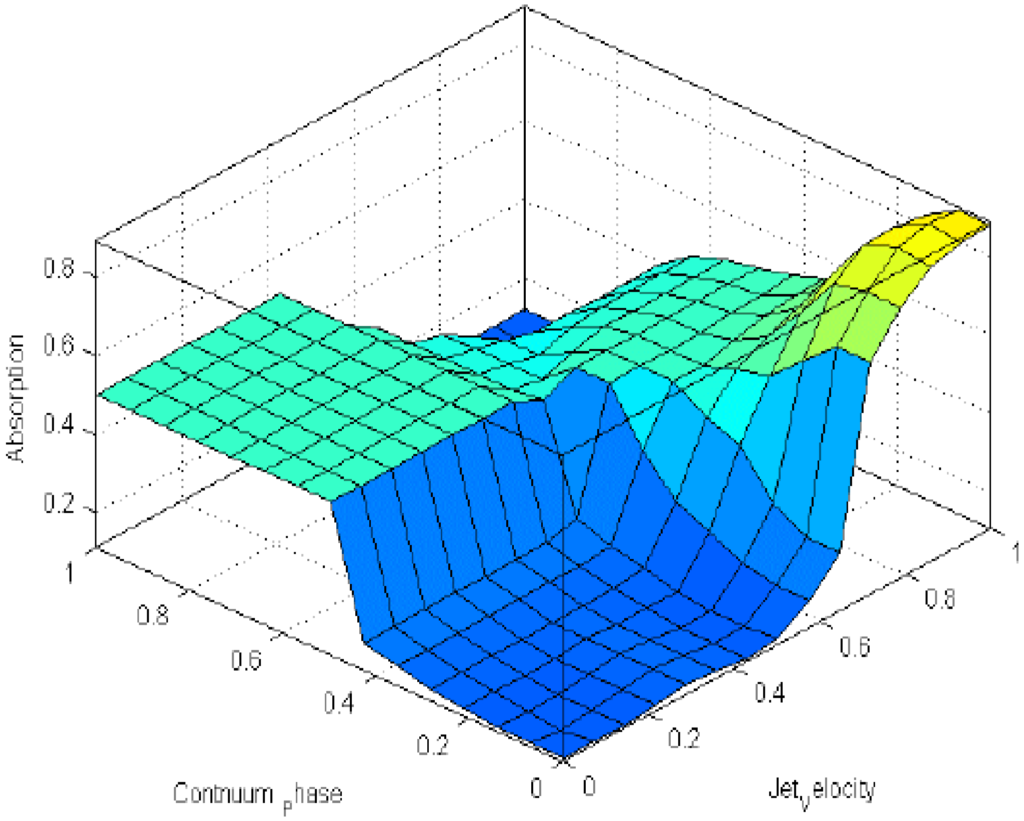

Figure 8: Relationship among jet velocity, phases in the control volume and absorption of gas into bottom by jet

SUMMARY

In this work, the high velocity jet was simulated. At comparative low velocities and at relative high velocities, the dip formation has trends. The bayou around dip has wavy effects and more detail insights should be done. The dip depth may be related to secondary fluid density, which has effects during mixing the fluids.

The dip-ping depth and shape of dip and density of the fluid as well as outflow location available may be further studied. The penetration of jet into fluid depends upon its velocity. There are many parts in the relation of velocity and dip depth. Some may be linear.

The point of diffraction is a point where the control of process may be designed. Angle at this location may be related to system of different air-fluids. For many other systems similar studies may be done and the point may be investigated for each system relating the common property. So, different systems may be investigated by making jet constant and varying the secondary fluid or vice versa.

Further investigations may be performed based on application orientation for different particular materials. Theoretical and experimental observations will draw more lines to investigate. Further single angle injection works [26] and many injection [25] works' findings may be investigated along.

Control the velocity of jet guides toward the condition of cleaning of container and to adjust the quality production during production process. It is also the case of controlling the size of bubble during production operation. Guiding the jet by its velocity may be a replacement of disk rotation.

ACKNOWLEDGMENTS

Dr. Basel A. Chemical Engineering

Dr. Yilbas B. Mechanical Engineering

REFERENCES

1. Khokhar, Z. H., Habib Zughbi, S. Sadiquee, 2003, Investigations of jet injection arrangements into main flow, International conference on chemical and bioprocess engineering, ICCBPE, Aug, Sabah, Malaysia.
2. A.M. Rothboce, A. Kbsek and A.W. Jones, 1942, The induction of water to the inlet air as a means of internal cooling in aircraft-engine cylinders. NACA report 756. Au. H20.
3. H. Lohe, 1966, Heat and mass transfer on top-blowing liquid surfaces. Chemie-Ing.-Techn., 38, 309-314.
4. L. K. Brumfield and T. G. Theofanous, 1976, Turbulent mass transfer in jet flow and bubble flow: A reappraisal of levich's theory, AIChE J., 22: 607-610

5. T. Aizawa, M. Kanakubo, Y. Ikushima, N. Saitoh, K. Arai, R.L. Smith Jr., 2004, Totsu.-window optical cell for absorption and emission studies of high-pressure liquids and supercritical fluids, J. Supercrit. Fluids, 29, 313. 317.
6. T. Aizawa, Y. Masuda, K. Minami, M. Kanakubo H. Nanjo, R.L. Smith, 2007, Direct observation of channel-tee mixing of hightemperature and high-pressure water, J. Supercrit, Fluids, 43, 222-227.
7. C. H. Lin. and E. E. O'Brien, 1974, Turbulent shear flow mixing and rapid chemical reactions: an analogy, J. Fluid Mech., 64, 195.
8. A. M. Ger and E. R. Holley, 1976, Comparison of single-point injection in pipe flow, J. Hydraul. Div. ASCE, 102 (HY 6), 731.
9. Zahid Hafeez Khokhar, Investigation of mixing in pipeline with side-, opposed-, and multiple-tees, Thesis, Nov 2002.
10. Z. H. Khokhar, H. D. Zughbi, R. N. Sharma, 2002, Mixing in pipeline with side-tee, 6th Saudi Engg Conference, Dec, 3-04-021, 2, 171-182
11. Z. H. Khokhar, 2002, Mixing in pipeline with side-tee, 6th Saudi Engg Conference, Dec, Presented.
12. M. Shilyaev, H. Khromova and S. Shirokova, 2015, The ways of mass transfer intensification in industrial jet scrubbers, In EPJ Web of Conferences (82, 01018). EDP Sciences.
13. M. Shilyaev, and E. M. Khromova, 2013, Modeling of heat and mass transfer and absorption-condensation dust and gas cleaning in jet scrubbers, Mass Transfer–Advances in Sustainable Energy and Environment Oriented Numerical Modeling.
14. S. S. Yoon, R. A. Jepsen, M. R. Nissen, T. J. O'Hern, 2007, Experimental investigation on splashing and nonlinear fingerlike instability of large water drops, Journal of Fluids and Structures, 23, 101-115.

15. Z. Pan, B.S. Wang and Z.P. Song, 2004, Research on underwater rocket separation performance, Journal of Ship Mechanics, 8(4), 22-26.

16. G. C. Gardner and I. G. Crow, 1973, Onset of entrainment and mass transfer with a jet directed at a two-phase interface, The Chemical Engineering Journal, 5(2), 267-273.

17. A. A. Sotiriadis, R. B. Thorpe and J. M. Smith, 2005, Bubble size and mass transfer characteristics of sparged downwards two-phase flow, Chemical engineering science, 60 (22), 5917-5929.

18. E. V. Safronova and G. N. Abaev, 2004. Mass exchange in a jet vessel, Chemical and Petroleum Engineering, 40 (5), 317-323.

19. E. Loth, and G.M. Faeth, 1990, Structure of plane underexpanded air jets into water, AIChE Journal, 36(6), 818-826.

20. Y. Chisti, M. Kasper, and M. Moo-Young, 1990, Mass transfer in external-loop airlift bioreactors using static mixers, The Canadian Journal of Chemical Engineering, 68 (1), 45-50.

21. M. K. Zakharov and V. G. Ainshtein, 1997, Calculation of process of desorption from liquid mixtures when the pressure is discharged, Chemistry and technology of fuels and oils, 33 (4), 202-206.

22. a. Investigations of lighter fluid jet injection velocity on dip depth formed at surface of heavier butt fluid, b. Communications: international conference on advances in mechanical and automation engineering-, Single air delivery through air onto water film, BS Yilbas, Shuja SZ, c. Zahid H. Khokhar, Mitteilungen Klosterneuburg Journal i. Single air delivery through air onto water film on flat bottom, ii. On first ignition in a covered metallic plate geometry, iii. Fast air jet reappearance within stagnant water layered at metallic wall boundary check, iv. Multiphase investigations of laminar air

jet penetrations at stagnant surface of fluid layered at metallic bottom in a rectangular channel open on other side.

23. Zahid H. Khokhar, 1. Fuzzy modeling of surface developments of plastics: additive based; 2.On a built fuzzy interface reaction process: range change effects; 3. Fuzzy modeling of a reaction: Introduction of a change; 4. Graduation of polymer by fuzzy model: a new sample; 5. Polymer fuzzy open up processing. 6. Mechanics of Composite Materials, MCM 2010. Institute of Polymer Mechanics: Sixteenth international conference: mechanics of composite materials: May, 2010 Riga, Latvia: Book of abstracts.
24. Zadeh, L. A., 1989, Knowledge representation in fuzzy logic, IEEE Transactions on Knowledge and Data Engineering, 1, 1, 89-100.
25. Zahid H. Khokhar, *1*. Several injections in spite of a single injection comparative commentary , Wulfenia Journal, *2*. Multiple injections into horizontal pipe Reduction in mixing downing length, Mitteilungen Klosterneuburg, Journal, *3*. On the bravais lattice from the chorus of water shell within the tee cross, JMEST, Journal of Multidisciplinary Engineering Science and Technology, Germany, *4*. Study of Numerous Injections into Horizontal Flow Stream at Low Temperature, Chemical Product and Process, Modeling, DGruter Journal, 5, 1, 2010, 27, *5*. An experimental and numerical predictions of multiple injections into horizontal flow to reduce length required for mixing, Proceedings of the V European Conference on Computational Fluid Dynamics ECCOMAS CFD 2010, Lisbon, Jun 2010, *6*. Book of Abstracts of the V European Conference on Computational Fluid Dynamics ECCOMAS CFD 2010, I and II, ISBN: 978-989-96778-0-7.
26. Zahid H. Khokhar, I. Effects of obliqueness of jet into horizontal flow, Mitteilungen Klosterneuburg Journal, II. On hot jet confinement into pipe flow: change in jet

delivery angle, Ciencia ET Journal, III. On injection posture infused into body, Kasmera Journal, IV. Effectiveness of jet injection within Horizontal downstream, Mitteilungen Klosterneuburg. V. Effects of angle jet into horizontal pipe: Center Oriented, Jokull Journal, VI. On adjusting abnormal side hot injection into cold water constant continuous flow, Wulfenia Journal, VII. Side oblique jet mixing measurements in pipeline flow, Mitteilungen Klosterneuburg Journal, VIII. Symmetric co- and counter- angle injection into horizontal pipeline flow comparison.

27. Reneker D., Chun I., 1996, Nanometre diameter fibres of polymer, produced by electrospinning. Nanotechnology, 7, 3, 216.