Vapour Adsorption and Recovery using Fluidized Bed Reactor: A Study

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Abstract - *Organic vapors cannot be vented to atmosphere directly. Their toxic effect needs to be suppressed or treated before venting it to the atmosphere. TCE is one of the pollutant which harms environment. So their toxicity should be minimized and try to avoid their direct entry into the atmosphere. Currently various organic vapours is being absorbed and recovered using adsorption which is generally carried out in cyclic batch process. The present work deals with the study of adsorption and recovery of TCE (the two important processes which play a vital role in process industries) in a Modified Fluidized Bed Reactor using activated carbon bed. The concept that is used behind the designing of the Modified Fluidized bed is being studied for the adsorption and recovery of TCE. The Computational Fluid Dynamics associated with the reactor is also studied. Considering the vast application of CFD, the external column of the reactor section is considered for computation and is being studied for different sets of velocities. The velocity and pressure contours are generated for the study of the fluid behaviour within the column to check for the negative pressure generation just below the expander section.*

Key Words: **Trichloroethylene (TCE), Pollutant, Fluidised bed Reactor, Adsorption, Recovery**

1. INTRODUCTION

Adsorption and Recovery are two of the important industrial processes that are widely used for various mass transfer operations. Mass transfer is the net movement of mass from one location, usually meaning stream, phase, fraction or component, to another [1]. Mass transfer occurs in many processes, such as absorption, evaporation, adsorption, drying, precipitation, membrane filtration, and distillation etc. **Adsorption** is the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface.[2] This process creates a film of the *adsorbate* on the surface of the adsorbent. This process differs from absorption, in which a fluid (the *absorbate*) is dissolved by or permeates a liquid or solid (the *absorbent*), respectively.[3] Adsorption is a surface-based process while absorption involves the whole volume of the material. Recovery is the evaluation of the completeness with which an initial raw material is used in separation technological processes(including concentration of mineral products, metallurgical processes and processes involving chemical technology).A raw material in technological processes is never completely separated into its constituent elements or compounds but rather the concentration of substances in the material changes upto the present value ,the recovery depends upon the initial concentration. Currently the organic vapours are adsorbed and recovered using the adsorption which is carried out in cyclic batch manner (adsorption and recovery in separate column) which is pretty time consuming and costly. So a research is ongoing to carry out this two processes within the same system .This would not only benefit the efficiency of the process but would also provide an alternative to the current one.

2. Materials and Operating Conditions:

The facilities required for the proposed project work are:

1. Fluidized bed reactor setup.
2. Condensing system.
3. Storage Tank.

2.1 Materials:

The materials used for the trial includes activated carbon having hydrodynamic radius between 0.25 to 5mm possessing high abrasion resistance and high thermal stability[4]. The fluid used is TCE (Trichloroethylene) which is synthetic, light sensitive having chloroform like odor [5].

2.2 Apparatus:

The Modified Fluidized Bed Setup (Made from SS316L) comprising up of heating system within was used for the study of the concept used for behind the design of the Modified Fluidized Bed Reactor.

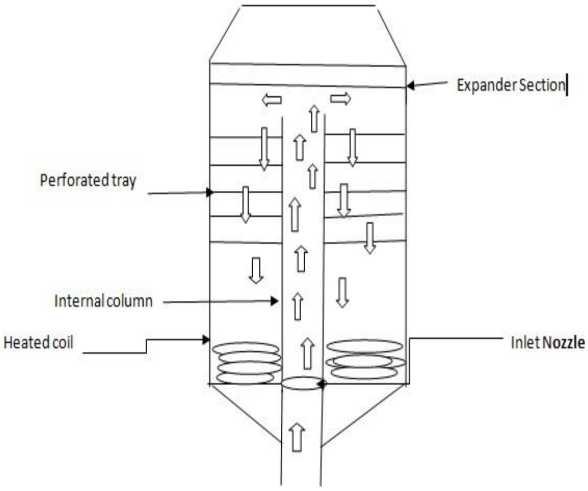


Fig 1: Modified Fluidized Bed Reactor

2.3 Experimental Methodology and Conceptualization:

The increase in Fluidized Bed Reactor use in today's industrial world is largely due to the inherent advantages of the technology [6,7].Uniform particle mixing, temperature gradients and its ability to operate in the continuous state allows the Fluidized Bed Reactor to take an advantage over a Packed Bed Reactor. In this Modified Fluidized Bed Reactor it consist of two type of reactor in one single system i.e. one internal and one external column. In this reactor we are going to carry out two processes at the same time within the same system. The granular activated carbon is injected into the fluidized bed reactor by the nozzle from the bottom at very high velocity (upto 2-3 times the minimum fluidization velocity in order to lift the particles and also to avoid backflow of them) and it passes to the all area in the reactor and at the top of reactor the bed is expanded and the velocity of the charging activated carbon is reached upto zero. When velocity of charging activated carbon reaches zero then it starts settling down into the trays. The trays are perforated in order to allow the particles to trickle down the bed. Once it reaches the bottom tray, TCE vapours are injected from the nozzle and mass transfer takes place between them. After a considerable amount of residence time the particles are settled in the area where the provision is made for accumulation of the particles. As soon as the settling down of the particles takes place desorption takes place by means of the heating coils. The heating is continued till the condensation limit is reached for TCE (generally it is non-condensable in ppm level).When the conversion to percentage level from ppm is reached the TCE vapours are further passed on to the condensing system to condense the TCE vapours and the residue of the activated carbon is collected from the bottom section of the reactor.

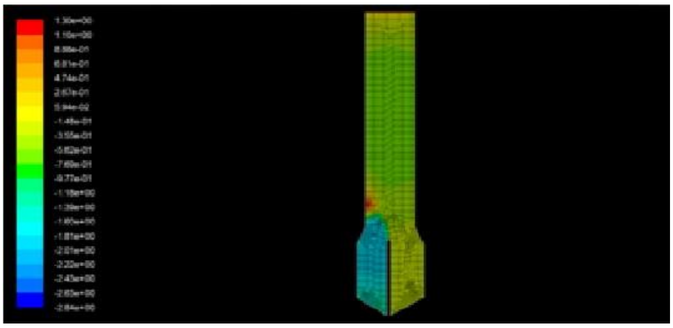
3: Computational Fluid Dynamics

Computational Fluid Dynamics or CFD is the analysis of systems involving fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer based simulation [8].

3.1 CFD Computation for External Column:

In this work we have carried out CFD for the external column by following the above methodology to study the fluid behavior within the column by plotting the pressure and velocity contours for different sets of velocities. At first, the problem is being formulated for the geometry of the external column along with the nozzle and a 2D mesh [8] is being generated with the exact dimensions and boundary conditions. The mesh generated is then imported and the input parameters are assigned accordingly. The most reliable k-ε model [9] is used for numerical computation and it is halted when the solutions are converged. In order to lift the solids from the bottom section of the column the negative (suction) pressure needs to be generated within the column. So the fluid pattern is being studied with the given sets of velocities and the region where the negative pressure is being generated.

I. Velocity 3.5m/s:



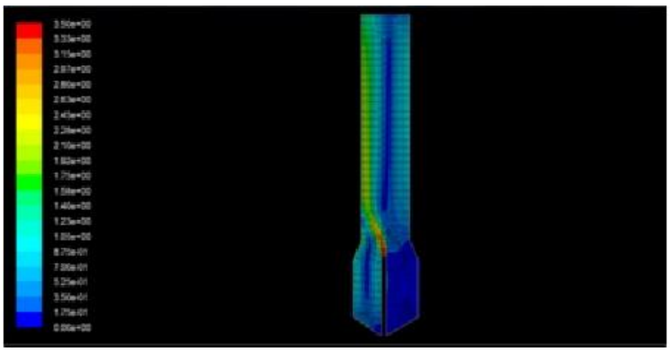


Fig 2: Contours of Static Pressure and velocity magnitude at velocity 3.5m/s

II. Velocity 8 m/s:

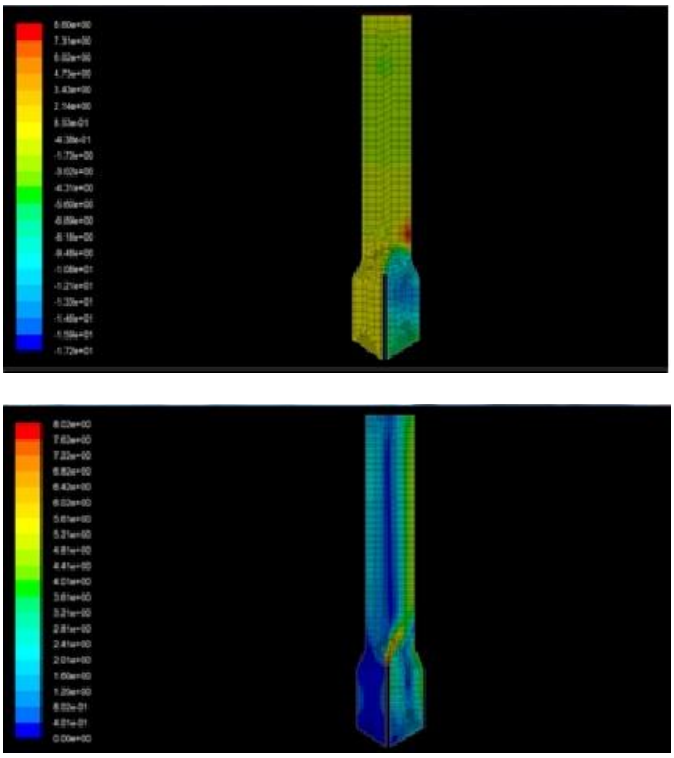


Fig 3: Contours of Static pressure and Velocity magnitude at velocity 8 m/s.

III. Velocity 13m/s:

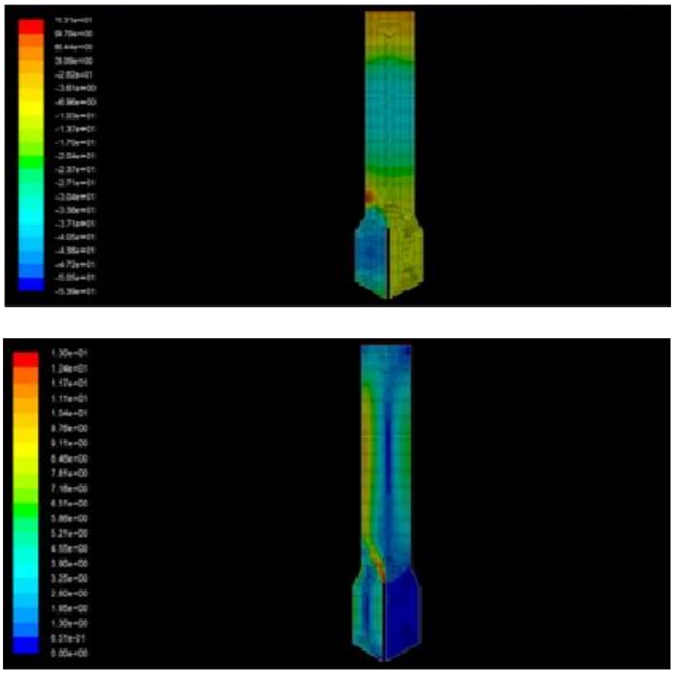


Fig 4: Contours of Static Pressure and Velocity magnitude at velocity 13m/s.

IV. Velocity15.6m/s:

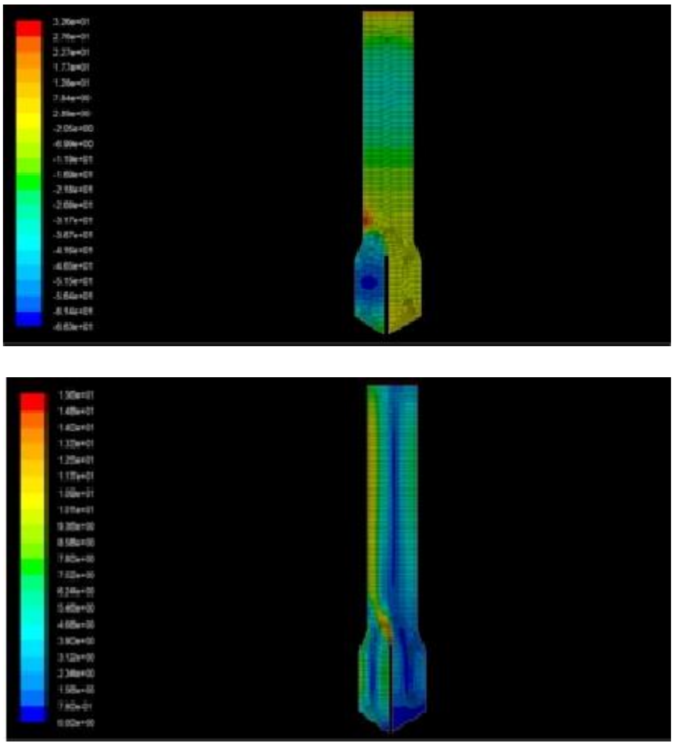


Fig 5: Contours of Static Pressure and Velocity magnitude at velocity 15.6m/s.

4: Results and Discussion:

The two important industrial processes i.e. adsorption and recovery are being studied along with their importance in recovering organic solvents. A new approach to carry out these processes using fluidization as the basic principle within the same system is studied along with the conceptualization of the design. This helped in understanding the basics of the Modified Fluidized Bed Reactor and its applicability. The External column geometry along with the expander section of the Fluidized Bed Reactor is used for CFD computation for studying the fluid behavior and pressure effects that are generated within the column. The velocity and pressure contours are being generated for random sets of velocities i.e. 3.5, 8, 13, 15.6 m/s. It was observed that the fluid profile required was almost close to the requirement at the velocity of 15.6m/s where the expander lifts the solids almost vertically and so was the pressure contours with minimum negative pressure requirement when compared with other sets of velocities.

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