

Chemical Processing in a Film Boiling Reactor

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Introduction

Controlled chemical change is almost always affected in the closed environment of a chemical reactor. Whether it is in the batch or flow mode, the systems are characterized by the confining walls of the reactor. This is a very natural environment for controlling any chemical process. In this presentation attention is called to the possibilities of an alternative approach. This involves using the extreme conditions that can be generated in the film boiling region of a liquid to cause reactions in liquids or components in liquid (for miscible mixtures). We term this reactor concept a "**film boiling reactor**" ("FIBOR"). The advantage of this process is its simplicity. Reactions occur on the hot surface of a heating element in the film boiling regime, or in the region immediately adjacent to the surface. The reaction is confined to the region between the solid surface and the gas-liquid interface. Thus the reactant can serve as its own insulator. The system can be very compact, with a small footprint and portable. It is easily maintained since the heated element can be readily changed. There are unique safety features since destruction of the vapor film will automatically shut down the reactor. In the following we will describe the phenomena, summarize calculations that define the conditions encountered in the reactor, show results on the conversion of methanol to carbon monoxide and describe possible extensions of the technology.

Background

When a sufficiently hot surface is placed in a liquid the first noticeable effect is the formation of bubbles on the surface under the action of nucleate boiling. As the surface temperature is increased, more and more bubbles are formed and at sufficiently high temperatures the bubbles coalesce and form a vapor blanket surrounding the surface. The volume of this film is the FIBOR. The vapor in the film flows around the surface under the action of buoyancy and escapes at the top in the form of bubbles which percolate through the liquid pool. As vapor flows along the surface it will react, either catalytically at the heated surface if the surface is coated with a suitable catalyst or by thermal decomposition if the vapor temperature is high enough. The bubbles carry the reaction products as they percolate upward, eventually releasing the internal vapors when they reach the free liquid surface of the reactant pool.

The film boiling process (without chemical reaction) is reasonably well understood, and detailed discussions can be found in standard texts [1]. Less understood is the film boiling process coupled with chemical change of the vapor [2-4]. Early studies [2] concluded that the change in heat transfer coefficient in methanol associated with a horizontal tube coated with platinum black is consistent with decomposition of methanol to carbon and monoxide, though direct measurements of product yields were not reported. The theoretical basis of the FIBOR concept was further recently developed [3,4]. We have now illustrated the viability of the FIBOR by direct measurements of carbon monoxide and hydrogen yields for catalytic conversion of saturated methanol with a platinum catalyst.

Results

A 5 mm platinum black coated tube was used as the reacting surface with saturated methanol as the reactant liquid. Since the reactant is introduced through the gas-liquid interface that surrounds the tube, there is a distribution of residence times. Combining mass and energy balance considerations with appropriate thermophysical properties of methanol and the rate expression deduced by experiments in a packed bed reactor [2] for methanol decomposition, flow rates, film thicknesses and the temperature fields were defined [3,4]. At the temperatures of interest radiation exerts little influence on the process. With the present physical configuration residence times are of the order of 10 msec. The situation thus approximates that of short contact time reactors. An apparatus was recently constructed and the experimental results confirm to a large extent the deductions from the calculations. Hydrogen yields of the order of several liters/minute have recently been found measured through gas chromatographic analysis carbon monoxide and hydrogen, which are the dominant produce species observed.

Discussion

These results represent a satisfactory proof of concept. The next steps will involve the application of this type of reactor to a variety of systems where the unique capabilities can be utilized. The direct application is the breakdown of heavy reactants to lighter constituents. Some examples include the breakdown of heavy oils to lighter and more useful components. It may well be possible to carry out such operations in the field. Another application is the use of the method for the destruction of chemical agents. Instead of moving the container to the incinerator as is the current procedure, the FIBOR could be operated on site. Furthermore, an important means of producing biodiesels is through decomposition of triglycerides. The byproduct glycerol may be destroyed with the same procedure, though the efficacy of the FIBOR for this application remains to be demonstrated. Work on some of these possibilities is currently underway.

For reactant mixtures, the creation of a FIBOR involves a distillation process in addition to the destruction reaction. A possible fundamental limitation is the difficulty in treating the heavier components of a mixture. Cycling the film boiling process may be an alternative approach. Thus, as the film collapses, low vapor pressure reactants can be brought into direct contact with the heating element that would remain at the high temperature for a short period of time. This will make the FIBOR a more general procedure and possibly permit the treatment of solids such as biomass, coal emulsions, etc. It may also serve as a means of destroying heavy hazardous chemicals in aqueous media. The scientific basis of such procedures rests on the stability of the films and can only be examined through experiments.

References

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