GAS-SOLIDS FLOWS IN DOWNERS:

HYDRODYNAMICS AND REACTOR MODELING

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DEPARTMENT OF CHEMICAL ENGINEERING

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by

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CERTIFICATE

This is to certify that the thesis entitled '***Gas-Solids Flows in Downers: Hydrodynamics and Reactor Modeling***' being submitted by **Ms. Suryawanshi Vaishali Uttamrao** to the Indian Institute of Technology, Delhi for award of Doctor of Philosophy is a record of bonafide research work carried out by her under my guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology, Delhi.

The research report and results presented in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Chemical engineers are pre-dominantly engaged in the design, scale-up and troubleshooting of process units for effecting potentially complex chemistries in a controlled environment. One such "reactor" that is being employed from several decades in various chemical and energy industries and in a number of applications of great economic value is the so called the circulating fluidized bed riser (CFBR). Employed in a variety of applications like fluid catalytic cracking (FCC) and partial oxidation of light paraffins, the CFBR loop usually consists of individual gas-solid contactors like fluidized beds, risers and downers. This thesis relates specifically to downers, though viewed in the general context of gas-solids dispersed flows, and in comparison to risers and fluidized beds.

In recent decades, developments in catalytic sciences, the drive for more profitable processes, as well as stringent environmental regulations demanding more efficient processes, have all motivated the search for the most optimal reactor for a certain chemical process. Certainly, with the development of fast acting catalysts and selective catalyst, the need of the hour is for having short contact time, narrow residence time and low back mixing reactors. The downer, which involves co-current downflow of fluid and solids, is a promising candidate as a short contact time reactor, since it closely follows this "wish-list".

This thesis specifically relates to computational fluid dynamic (CFD) models of downers. Euler-Euler modeling of downers has been presented and the developed models are validated against reliable experimental data. The model is optimized for closures that are robust and best describe the underlying flow phenomena and the dependencies between the key variables. Subsequently, this model has been extended to a reactor model for partial oxidation of n-butane to maleic anydride. This reactor model is used to make comparative

predictions of downers and risers as reactors for partial oxidation (the use of risers being the current technology). Metrics by which downers may outperform risers as partial oxidation reactors are outlined.

In the final part of this thesis, Euler-Lagrange modeling of downers is presented in which each particle in the solids ensemble is tracked. This model is used to make various qualitative and quantitative predictions about flow features, fluctuating solids velocity and mesoscale, metastable structures that are formed in the flow field.

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