CHAPTER 3

OBJECTIVES AND SALIENT FEATURES

3.1 PROBLEM DEFINITION

It is the need of the day to develop new energy efficient processes and to seek for the opportunities to make the existing processes more energy efficient. Aeration is one of the inevitable energy intensive processes that finds wide applications including oxidation of process streams, treatment of wastewater etc. Conventional methods of aeration involves the use of compressor/blower for increasing the pressure of the atmospheric air and sparger for distribution of air into the liquid in the process vessel (Joshi & Sharma 1977; White & De Villiers 1977; Sawant & Joshi 1979; Raidoo et al. 1987; Rielly et al. 1992; Chang & Morsi 1992a; Saravanan et al. 1994; Forrester & Rielly 1994) Air-inducing reactors were developed in order to reduce the power consumption for aeration process and several modifications were proposed in the design and fabrication of air-inducing reactors over past three decades. In addition to the air-inducing reactor, there is another similar device called self-inducing reactor. Though the mechanism air-inducing reactor and self-inducing reactor are exactly the same, there is a difference based on application part or specifically based on the gas that is induced. If the induced gas is only air, the reactor is called an air-inducing reactor. If any gas, including air, is induced then the reactor is called a self-inducing reactor. The air inducing reactor is mainly used for aeration and oxidation whereas the self-inducing reactor is used for alkylation, ozonolysis, ethoxylation, catalytic hydrogenation, suspension polymerization, oxidative leaching of ores,
wastewater treatment, chlorination, ammonolysis, oxidation, etc., where it is very much important to have complete utilization of the gas. In a self-inducing reactor involving gas-liquid operation, if the per pass conversion of the gas is considerably low, in order to improve the utilization of gas, the gas must be recirculated many times within the liquid in the reactor. This can be attained easily with the use of self-inducing impeller. Therefore it is important to use self-inducing reactors for improving the effective utilization of the gas that is used for the gas-liquid operation (Aldrich & Deventer 1994; Saravanan et al. 1994; Heim et al. 1995; Hsu & Huang 1996; Tekie et al. 1997; Hsu et al. 1997; Patwardhan & Joshi 1997; Forrester et al. 1998; Patwardhan & Joshi 1999; Poncin et al. 2002; Conway et al. 2002; Ruthiya et al. 2003; Lemoine et al. 2003; Chen et al. 2003; Lin & Wang 2003; Kluytmans et al. 2003; Ma et al. 2003; Lin & Wang 2003; Jafari & Mohammadzadeh 2004; Patil et al. 2004; Patil et al. 2005; Kumar et al. 2005; Jafari & Mohammadzadeh 2005; Hsu et al. 2005; Girgin et al. 2006; Deshmukh et al. 2006; Deshmukh & Joshi 2006; Murthy et al. 2007; Scargiali et al. 2007; Vesselinov et al. 2008; Kasundra et al. 2008; Ju et al. 2009; Linga et al. 2010; Achouri et al. 2013; Wang et al. 2013; Hong et al. 2014; Ye et al. 2015).

From the literature analysis, it was found that many investigators made developments in the self-inducing reactors for minimizing the power requirement for gas-liquid operations and gas-liquid-solid three phase operations. The self-inducing reactors found in the literature are of two types viz., stator-rotor type (or draft tube type) and hollow-shaft and hollow-impeller type. Both types of self-inducing impellers found in the literature are useful and advantageous for many gas-liquid and gas-liquid-solid operations. But the major limitations in the design of self-inducing impellers found in the literature are (1) they can only be used for reactors that are newly fabricated reactors or a major modification is required for converting a conventional agitated vessel into air inducing reactor, and (2) recirculation of gas into the
liquid is difficult. No literature support is available for the conversion of conventional agitated vessel into air-inducing reactor. Adequate literature support could not be found for the case of high density liquid system as the working for air-inducing reactor. Similarly, limited number literature could be found for the suspension of solid particles using air inducing impeller system. The objective of the present study is to simplify the self-inducing mechanism and to convert the existing conventional agitated vessel into air inducing reactor with a retrofitting type of modification in the system. In order to reach the objectives, a specially designed air inducing tube-set was fabricated, which when attached to the impeller shaft of the agitated vessel converted it into an air-inducing reactor. The performance of the air-inducing tube-set was analyzed by carrying out hydrodynamic study using water as the working fluid, hydrodynamic study using sodium chloride solution in water as the working fluid, particle suspension study for the suspension of sand particle in water, and mass transfer study by measuring dissolved oxygen in water.

3.2 OBJECTIVES OF THE STUDY

Based on the review of literature, the following objectives were framed for the present work:

- To eliminate the complications involved in the design and fabrication of self-inducing impeller so that an existing conventional mechanically agitated vessel could be converted into an air-inducing reactor by a retrofitting type of modification in the existing system.

- To study the hydrodynamic behavior of the self-inducing reactor fitted with a novel air-inducing tube-set by observing the critical speed for air-induction, power consumption, and fractional gas holdup for various liquid levels in the tank, and orifice submergence depth.
• To use the novel air-inducing impeller system for hydrodynamic studies using sodium chloride solution in water as working fluids for observing the effect of impeller speed, orifice submergence depth, total gas-free liquid level and concentration of sodium chloride solution on power consumption and fractional gas holdup.

• To study the performance of the novel air-inducing impeller for the suspension of sand particles in water for observing the effects of particle size and solid loading on power required for agitation, and fractional gas holdup.

• To evaluate the mass transfer performance of air-inducing reactor by measuring the dissolved oxygen content in water and mass transfer coefficient.

The present work involves a detailed experimental investigation and analysis of the effects of operating variables on the performance of air-inducing impellers to achieve the above mentioned objectives. The experimental investigation is aimed at the analysis of applicability and suitability of novel air-inducing impeller system for the various purposes listed above.

3.3 SALIENT FEATURES OF THE CURRENT WORK

The significant features of the current work can be summarized as follows:

• Hydrodynamic studies on the air-inducing impeller system by taking water as the working fluid for studying the effects of orifice submergence depth, total gas-free liquid level, off-bottom clearance of the impeller on power consumption and fractional gas holdup.
- Hydrodynamic studies using sodium chloride solution in water as the working fluid for observing the effects of concentration of sodium chloride in the working fluid, total gas-free liquid level in the tank, and orifice submergence depth on power consumption for aeration and fractional gas holdup in the tank.

- Studies on suspension of sand particles in water using self-inducing impeller system by observing the effects of solid particle size and weight percentage of solid particles loaded on power consumption and fractional gas holdup in the vessel.

- Mass transfer studies on self-inducing impeller system by observing the effects of orifice submergence depth, total gas-free liquid level and impeller speed on dissolved oxygen content in water and mass transfer coefficient.

In order to achieve the above stated objectives, a detailed experimental investigation has been carried out. The details of the experimental setup, procedure, and collection of experimental data are described in the forthcoming chapter.