Pak j. sci. ind. res., vol. 32, no. 7, July 1989

GAS HANDLING CAPACITY OF AN IMPELLER

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(Received August 1, 1988; revised June 5, 1989)

The criteria for gas handling capacity of an impeller is defined in this paper. Measurements are formed on different kinds of impellers including: radial, axial, tangential and mixed flow types. Different zones of gas dispersion are indentified with the help of Stroboscopic observations. Finally, results are expressed in terms of flow numbers as a function of changes in the flow pattern of the gas.

Key words: Flooding, Dispersion, Gas mixing.

INTRODUCTION

The most important parameter in gas dispersion is the quantity of gas an impeller can disperse efficiently into bubbles and distribute throughout the vessel.

In the literature, researchers have used the term 'flooding' to describe the unsatisfactory operation of an impeller with respect to the gas dispersion and the term 'loading' has been frequently used to describe the condition when the gas is uniformly distributed throughout the tank. At the 'flooding' condition, the gas rises to the liquid surface along the impeller axis as a swarm of bubbles without being distributed in the vessle. When the impeller is 'loaded' the bubbles are throughly mixed in the contents of the tank.

Several authors have studied this phenomenon (Zwietering [1], Rushton and Bimbinet [2], Biesecker [3], Nienow *et. al.* [4], Wiedmann *et. al.* [5], Warmoeskerken and Smith, [6] Pandit and Joshi [7] and a review of the literature indicated that there is a lot of controvesy regarding the basic definition of 'flooding', and several different predictions of the transition between "loaded' and 'flooded' conditions have been given. The obvious result is that the proposed correlations often conflict and are difficult to reconcile.

The researchers have tried to relate the flooding phenomenon with the change in bulk flow pattern, change in gassed power demand, step increase in power at flooding, and with the formation of large cavities behind the impeller blades. It appears that the relations presented in the literature for the flooding phenomenon are mostly empirical and are based on dimensional analysis.

More recently, Warmoeskerken and Smith [8] and Warmoeskerken [9] have analysed critically the available information in this area. They have proposed a clear definition of flooding, and from the theoretical analysis, derived a linear relation between the gas flow number and the impeller Froude number, at the onset of flooding.

In this study, the term 'gas handling capacity' is used instead of 'flooding' to decide the maximum amount of gas an impeller can handle.

Saleemi [10], has clearly indicated that the gas dispersion is controlled by the phenomena occurring in the wake of the blade and the bubbles formed by the blades are being distributed in the vessel by the pumping action of the impeller.

It was also shown that, with an increase in gas rate, above the critical gas-handling capacity, cavity formation will effect the ability of the blades to make small bubbles, leading to ineffective gas dispersion.

However, it is established Keller [10], Warmoeskerken [9] that in a gassed system the pumping rate is a function of the gas rate, and will be diminished by an amount depending upon the size of the cavities behind the blades. The following reasons can be considered responsible for the reduction in pumping rate:

(i) Blocking effect of cavities.
(ii) Density reduction of the medium due to bubble swarms.
(iii) Power reduction in the aerated conditions.

In order to define gas handling capacity for an impeller, one has to compromise between the pumping rate and the quality of gas dispersion.

In this study, the gas handling capacity is described as the amount of gas at which the transition from the gas-flow-controlled dispersion to the cavity-controlled dispersion occurs (see Fig. 1).

EXPERIMENTAL

1. *Experimental setup.* A Schematic diagram of the experimental rig is given in Fig. 2, and a photograph is shown in Plate 1. The essential features of the rig can be divided into five parts: (i) Power Source to provide agitation. (ii) Bearings supported construction to measure

torque. (iii) Mixing Vessel. (iv) Viewing system for stroboscopic studies. (v) Pressure measuring probe.

An electronically-controlled drill (Metabo Company) was used to provide agitation power. With the help of two speed-reduction gears, the speed could be varied between 0–800 or 0–2700 rpm at full load. The rated maximum power input was 1 K Watt and output was 610 Watts. The drill stand assembly was mounted vertically upside down with the support of two self-aligning bearings; coaxial with the axis of drill output spindle. The bearings took the axial and radial loads, and the whole assembly turned freely on its axis.

A square shaped vessel was used due to ease of construction and also because of its common usage in the processing industry. The dimensions of the mixing vessel and baffle design are shown in Fig. 3. The baffles were used on the side walls instead of corners and whole vessel assembly was fabricated from perspex. A false bottom was used to support the baffles. A teflon bearing was provided in the centre of the false bottom to hold the impeller shaft in

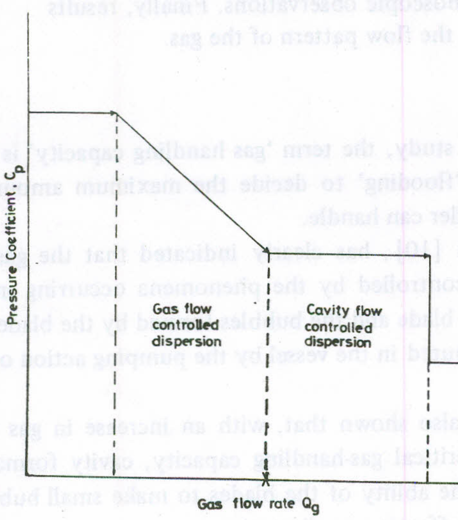

Fig. 1. Impeller gas handling criterion.

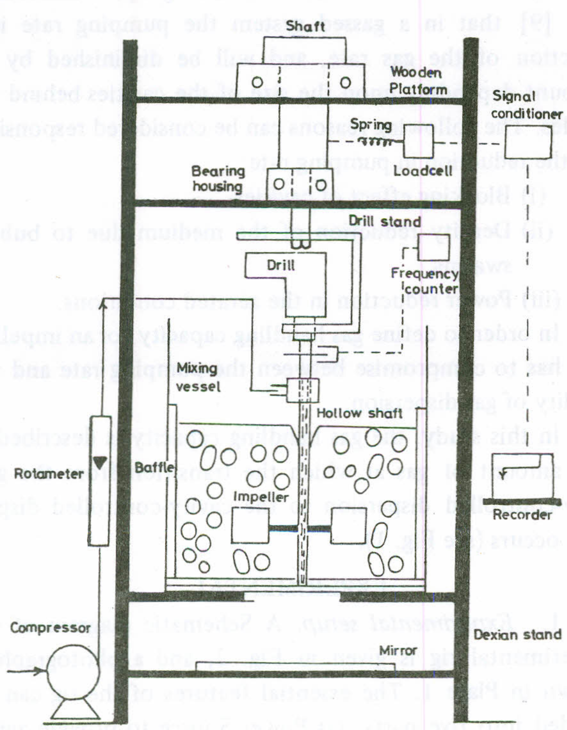

Fig. 2. Schematic of the experimental rig.

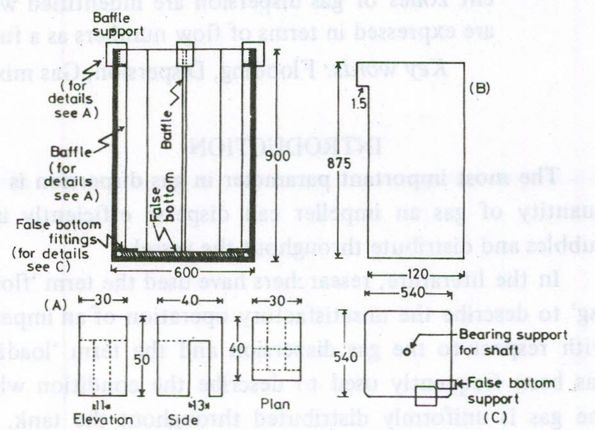

Fig. 3. Sketch of the mixing vessel and baffle details (all dimensions are in mm).

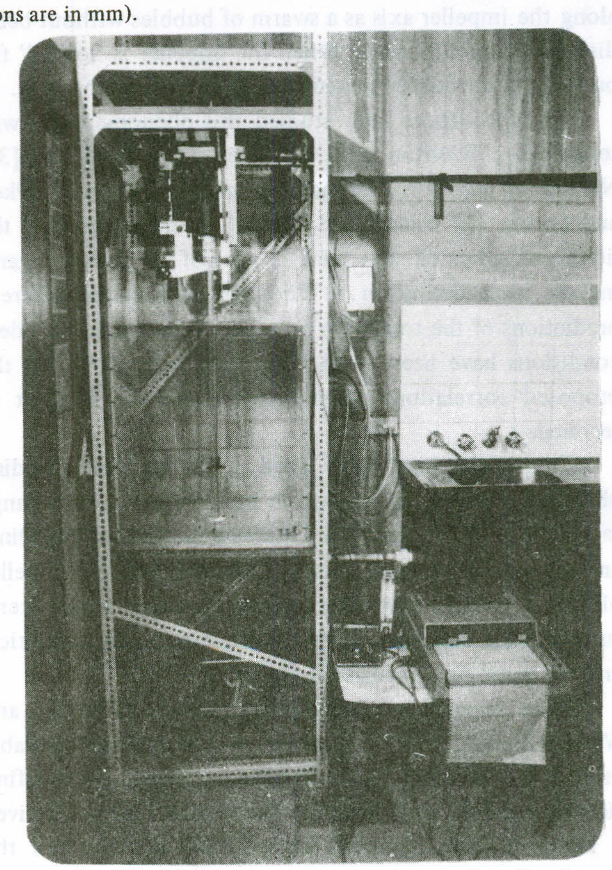

Plate 1. Photograph of the experimental rig.

order to prevent wobble at higher speeds. The liquid depth was kept at 68.5 cm, sufficient to prevent air entrainment from the surface even at high tip velocity of the order of 10 m/sec. The liquid used in the study was water while air was used for dispersion.

2. *Stroboscopic observations.* The gas handling capacity was determined by observing the behaviour of the pressure in the wake of the blade as the gas flow rate was increased. With increase in gas rate, when large cavities were formed, the pressure behind the blade became constant.

After a series of experiments, however, it was realized from the stroboscopic observations that the sparged gas was not distributing equally on all blades. There were cavities of different sizes on the blades depending upon the amount of gas approaching the blades. Due to unequal distribution of the gas it was observed that different hydrodynamic of the gas it was observed that different hydrodynamic conditions were prevailing on the various blades, ranging from no cavity at all, to completely blanketed blades. It appeared impossible to distribute the sparged gas equally to all the blades, because the amount of gas which a blade can collect depends upon its pressure profile, the size of any cavity already existing on the blade and those ahead of it, and the flow pattern of the liquid under the impeller disc.

It was therefore decided that due to unequal distribution of gas on the blades, it was not reasonable to draw conclusions about the gas handling capacity from the knowledge of the one blade pressure reading. The only alternative was to use separate pressure probes on all the blades, which was found impracticable.

Eventually, the gas handling capacities of the impellers (reported next section) were determined by observation of the transition from one state to the other (zone II to III) with stroboscopic light source.

3. *Impellers.* In this study, eleven different impellers were used which include radial, axial, tangential and of mixed-flow types. Details of the impellers used are shown in Plate 2 and Table 1.

The number designated to the impellers in the Table will be used to indentify them in further discussion.

RESULTS AND DISCUSSION

Gas handling capacities expressed in terms of dimensionless gas flow numbers are shown in Fig. 4 with tip speed. It can be seen that gas handling capacity for each impeller is almost constant with tip speed. An average value for each impeller was calculated and is listed in Table 2.

The experimental work indicated that there are two different routes for the sparged gas to enter into vortices, i.e. (i) Direct loading, (ii) Indirect loading.

In the case of direct loading, the sparged gas goes straight to the rear face of the blades and is dispersed there. It was seen that the impellers (except 9) with flow action in the same direction as the rising gas will have direct gas loading. For indirect loading, the sparged gas enters in the rear of the blade through recirculation of bubbles, with the liquid flow. This was observed with axial flow impellers like propeller [9].

Table 1. Details of the impellers.

Impeller No.	Name	Diameter of impeller (mm)	Blade dimension (mm)	Vortex trailing position (pressure measurement position)
1	2 Flat bladed disc turbine	100	L = 25 B = 20	¼ of blade length from inside edge of blade.
2	6 Flat bladed disc turbine	67	L = 16.75 B = 13.4	"
3.	6 Backward inclined bladed disc turbine	67	L = 22.0 B = 13.5	"
4	6 Bladed pumping up disc turbine	67	L = 16.5 B = 19	¼ of blade length from outside edge of blade.
5	8 Vanes disc turbine	67	L = 30 B = 9	"
6	6 Flat bladed hub turbine	64	L = 22 B = 8	¼ of blade length from inside blade edge.
7	6 Bladed spiral backswept turbine	76	L = 28 B = 9.5	"
8	6 Bladed axial flow turbine	76	L = 27.5 B = 12.5	¼ of blade length from outside blade edge.
9	3 Bladed marine propeller	80		"
10	2 Flat bladed disc turbine	100	L = 25 B = 40	¼ of blade length from inside edge.
11	6 Flat bladed disc turbine	50	L = 12.5 B = 10	"

It was seen that down ward pumping action of the propeller took the sparged gas as a mixture of bubbles into the recirculation loop. These bubbles were seen breaking into small bubbles as they entered into vortices. As may be observed from Table 2. gas handling capacity is a function of the blade area [1,10], the number of blades [1,2], the total length of blade emanating shear layers [4,5], and the liquid flow pattern [9].

Table 2. Results of gas handling capacities.

Impeller No.	Gas flow number (Qg/ND^3)	Gas flow number/blade
1	0.0162	0.0081
2	0.040	0.0067
3	0.040	0.0067
4	0.024	0.0040
5	0.033	0.0041
6	0.040	0.0067
7	0.038	0.0063
8	0.039	0.0065
*9	0.000	0.0000
10	0.043	0.0210
11	0.038	0.0063

*9 Indirect loading.

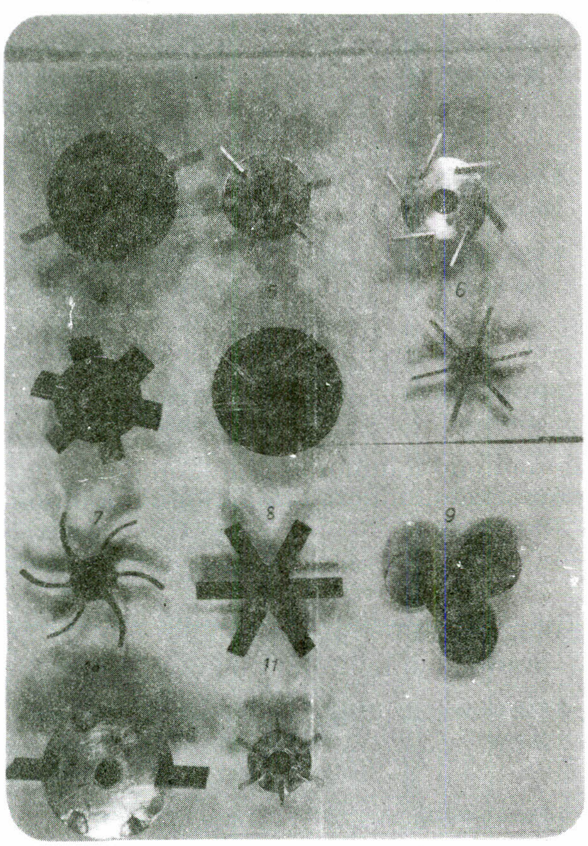

Plate 2. Impellers used in the study.

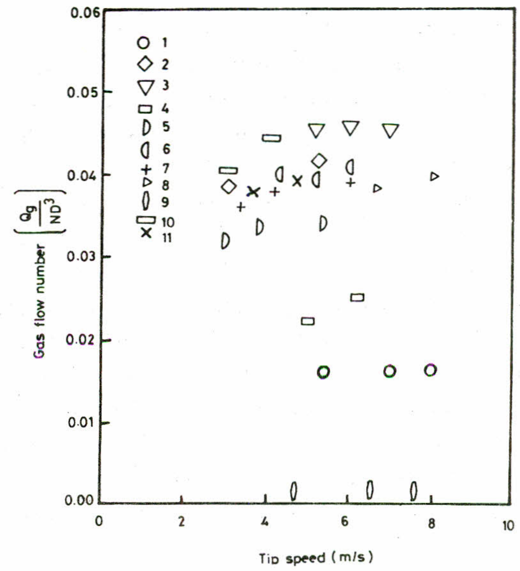

Fig. 4. Gas handling capacities (gas rates at transition from gas controlled dispersion to cavity controlled dispersion) of the impellers with tip speed.

CONCLUSIONS

In the present study, the term 'gas handling capacity' is used instead of 'flooding' to decide the maximum amount of gas an impeller can handle. It was seen that gas dispersion is controlled by the phenomena occurring in the wake of the blade, and the bubbles formed by the blades are being distributed in the vessel by the pumping action of the impeller. The pumping rate is a function of the gas rate and starts diminishing by an amount depending upon the gas rate. The gas handling capacity as described here is the amount of the gas at which there is a compromise between the phenomena of gas dispersion and pumping action.

From this study, it can be concluded that the gas handling capacity depends on the nature and shape of the impeller. Experiments have shown that it is a strong function of impeller blade area, the number of blades, the total length of the blade emanating shear layers and the liquid flow pattern.

Nomenclature

Q_g = Gas flow rate (m^3/sec).
D = Diameter of impeller (m)
N = Rotational speed of impeller (1/sec).

Acknowledgement. One of the authors (ARS) would like to acknowlege the grant of scholarship by the University of Newcastle Australia to undertake the present study.

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