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LIQUID HOLDUP OF FOAM AS AN INDEX FOR MECHANICAL FOAM-CONTROL IN GAS-LIQUID CONTACTOR

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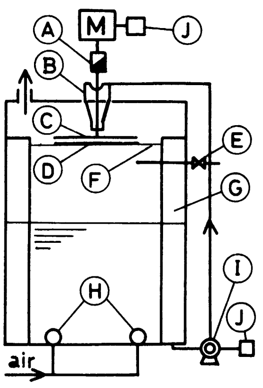
Liquid holdup of foam generated in a gas-liquid contactor was measured under mechanical foam control with a rotating disk foam-breaker(MFRD). The results showed that liquid holdup of foam not only is an index of dynamic foaming state of the contactor but also provides a good measure for effective operation of MFRD.

Foam-breaking systems on a purely mechanical basis, which do not give undesirable influence neither production, separation nor purification unlike the control by anti-foam agents,$^{1)}$ have long been attracted attention of the engineers.$^{1-2)}$ A number of mechanical methods have been proposed, however, none of them is entirely satisfactory or universally applicable to foam control. The primary reason is considered to be due to the situation that the empirical countermeasure has since been adopted for the foam control without the fundamental knowledge on foaming state of the gas-liquid contactor. Many studies have been reported on the nature of foam in a foam-breaking system.$^{3)}$ However, little information has yet been available on the nature of foam in a mechanical foam-controlling system where successive generation, collapse and circulation of foam take place within a limited head space of the contactor or on the relation between other physicochemical properties of foam in such a dynamic foam-controlling system and the difficulty of mechanical foam-breaking. Above apparently implies the necessity of finding a new foam index which reflects foaming state of the contactor under foam control and provides also a good measure of operating the foam-breaker effectively. Previously, we developed a rotating disk foam-breaker(MFRD) as a new type of mechanical foam-breaker.$^{4)}$ In deducing which nature of foam reflect foaming state of the contactor under foam control, principles of foam-breaking by MFRD may be a help. As already described, MFRD achieves foam-breaking by means of impact action of liquid particles from the disk against foam ascending from the aerated liquid. Reffering to this foam-breaking mechanism, it is conceivable that the foam-breaking capacity of MFRD is largely subjected to the effect of the weight of foam, i.e., whether foam is light or heavy. Assuming that foam containing a larger amount of the liquid(i.e., heavier foam) has more resistance with respect to destruction by a physical external force and as a result requires more impact energy of dispersed liquid particles for foam-breaking compared to foam of less liquid content(i.e., lighter foam), it is supposed that the weight of foam is heavy or not may be a measure of the foam nature which depicts a significant aspect of foaming state of the contactor under mechanical foam-breaking conditions. Whether foam is light or heavy, namely dry or wet, can be determined easily in terms of the liquid content in foam, i.e., liquid holdup of foam which is defined as the volume fraction of liquid in foam. In this work, for a foaming system using MFRD as a foam controlling apparatus, liquid holdup of foam is measured by varying operational variables of the contactor. The relation between the changes in liquid holdup of foam and the operational conditions of the contactor is investigated. How the change in liquid holdup of foam is related to hardness or ease of mechanical foam-breaking also is discussed.

The experimental set-up is shown in Fig.1. As the contactor, a vessel of 0.23 m in diameter D_T, which equipped with six ball spargers(0.015 m in diameter with average pore openings of 25 μm) and four baffle plates(0.1D_T in width), was used. A steel disk of 0.18 m in diameter was set in the head space of the vessel holding the ratio of D_T to disk height H_d at 0.85. A required amount of liquid for foam-breaking was fed continuously and uniformly at near the center of a disk through an annular feeder from the bottom by a roller pump. Also, a disk the diameter of which was the same as that of the rotating disk was fitted immediately underneath the rotating disk. This stationary disk contributes to prevent ascending foam from coming in direct contact with the lower surface of the rotating disk and to allow foam to pass through an annular area S_a separated by the rotating disk and vessel wall. Further details for the apparatus and experimental methods are given in our previous paper.4) Power consumption for foam-breaking with MFRD, i.e., power P_{KC} for liquid dispersion by the disk, was measured from the difference in torque meter readings between rotation during foam-breaking and that in air alone. Sampling of foam was carried out in a method using the glass tube, which was similar to that employed in the study of foam bed contactor.5) The glass tube was fitted to the wall at the height of 0.24 m from the bottom and was length-variable so that foam at different radial positions from the wall could be sampled. Foam the average size of which was in the range between 0.0012 and 0.0015 m in diameter was guided quickly from 0.004 m diameter glass tubes into graduated tubes(0.015 m in diameter and 0.11 m in height) where the pressure was slightly reduced by an aspirating pump. Sampling time was controlled constantly within 3 - 5 seconds by adjusting the intratubal pressure. Obtaining the sampled volume V_f and liquified volume V_L of foam, fractional local liquid holdup ε_L of foam was determined from the relation of $\varepsilon_L=V_L/V_f$. The foaming liquid used at 293 K was a diluted solution of commercial anionic soft-type detergent(The Lion Oil and Fat Co., Lipon F).6) The density of the liquid was 999 kg/m^3, the viscosity 1.00 mPa.s and the surface tension 38.6 mN/m. Also, the foaminess7) of the liquid was 480 seconds, and the half-life about 4,200 seconds.

In MFRD, the increase and decrease in the critical disk speed N_c required for foam-breaking reflect hardness or ease of foam-breaking. Figure 2 shows the results of N_c measured by varying the gas velocity U_g based on the vessel bottom and the working volume V, when the liquid feed rate W onto the disk is 0.01L/s. The



A.Torque meter
B.Liquid feeder
C.Rotating disk
D.Fixed disk
E.Sampling tap
F.Steel bar
G.Baffle plate
H.Ball sparger
I.Roller pump
J.Controller

Fig.1. Schematic diagram of apparatus.

results of foam-breaking power P_{KC} measured simultaneously are also shown in the figures as broken lines. Solid lines show the transient state from the foam-breaking to the non-foam-breaking regions, and the areas(the oblique-lined areas) below the lines show the regions of non-foam-breaking. At a disk speed below the critical one, foam which was not broken due to a less amount of dispersion energy of liquid particles from the disk starts to escape through the gap between the disk and vessel wall and overflows from the vessel quickly. For the effects of U_g and V on N_c or P_{KC}, as shown in the figures, both N_c and P_{KC} tended to increase with the increases in U_g and V, which also showed that the larger N_c, the higher the required P_{KC} at which foam-breaking was carried out. These mean that there occurs a less foam-breakable tendency due to the increased foaming intensity with the increases in U_g and V. In order to examine the relation between the change in foam-breaking behavior as shown above and the change in liquid holdup of foam generated, liquid holdup of foam in the head space of the vessel was then measured at the same conditions as in Fig.2. Firstly, the change in local liquid holdup ε_L of foam with changing the radial distance R from the wall was investigated. Figures 3-a and 3-b show the radial distribution of ε_L when U_g and V were varied respectively. As for the effects of U_g and V on ε_L, as is clear from the figures, ε_L on the whole is found to grow larger when U_g and V increase. In view of the foam-breaking mechanism of MFRD that foam-breaking is achieved by dint of impact action between the foam ascending through S_a and the dispersed liquid particles from the disk, mean value of ε_L based on S_a, namely, averaged liquid holdup $\bar{\varepsilon}_L$ of foam at the radial position from the wall to directly under the edge of the disk, was then evaluated. The results of $\bar{\varepsilon}_L$ plotted against U_g and V, which was obtained by graphical integration from ε_L data in Fig.3, are shown in Fig.4. It is found from this figure that $\bar{\varepsilon}_L$ grows larger when U_g and V increase, namely: the higher U_g which is considered to be directly proportional to the generation rate of foam from the liquid surface and the more decrease of the space between the disk and the liquid surface with the in-

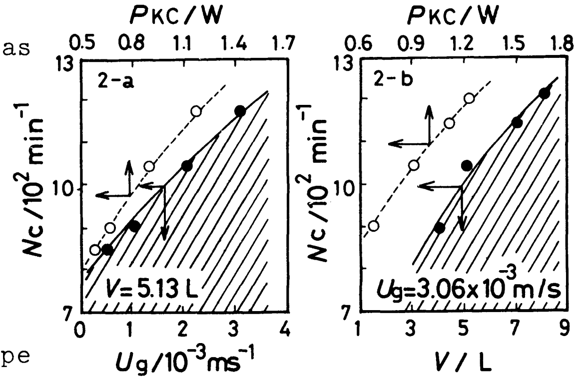


Fig.2. Results of N_c and P_{KC}.

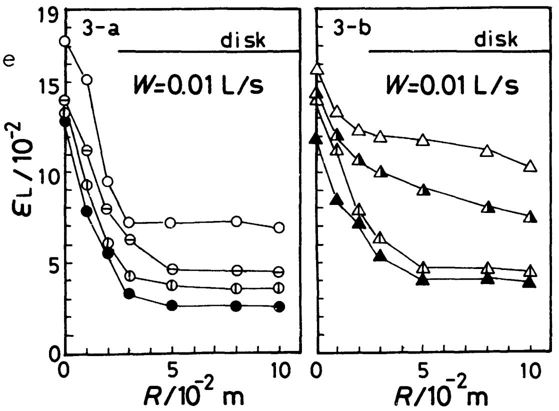


Fig.3. Radial distribution of ε_L.
3-a: V=5.13 L; U_gx10^3(m/s): ●;0.514, ⦶;1.03, ⊖;2.06, ○;3.09
3-b: U_g=2.06x10^{-3} m/s; V(L): ▲;4.00, ◭;5.13, ◬;7.00, △;8.00

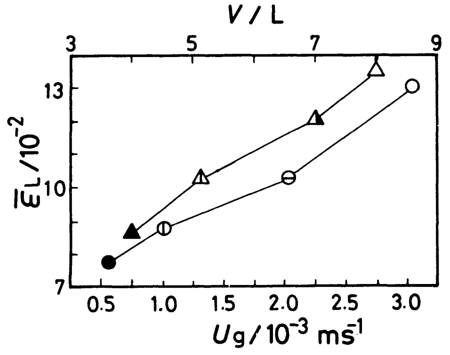


Fig.4. Relationship between $\bar{\varepsilon}_L$ and operating conditions (keys for lower and upper scales are the same as in Figs.3-a and 3-b respectively).

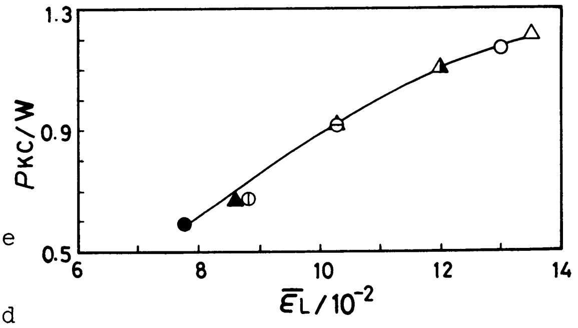


Fig.5. Relationship between $\bar{\varepsilon}_L$ and P_{KC} (keys are the same as in Fig.3).

crease in V(i.e., the narrower the foam-ascending section from the liquid surface to the disk), the larger $\bar{\varepsilon}_L$ is. The cause for the increase in $\bar{\varepsilon}_L$ with the increase in U_g may be ascribed to the increased liquid entrainment in foam with the increase in U_g and the cause for the increase in $\bar{\varepsilon}_L$ with the increase in V to less drainage of the liquid from foam by gravitation due to the decreased vertical distance with the increase in V. Anyway, the results shown in Fig.4 clearly suggest that $\bar{\varepsilon}_L$ is a significant index which reflects dynamic foaming capacity of the vessel under mechanical foam control due to variation of operational conditions. Secondly, whether this foam index is a measure for effective operation of MFRD or not was further investigated in terms of P_{KC}. The results are shown in Fig.5, in which P_{KC} is plotted against $\bar{\varepsilon}_L$. As clearly seen in the figure, the increase in $\bar{\varepsilon}_L$ and that in P_{KC} well corresponded to each other, showing that higher $\bar{\varepsilon}_L$ requires more energy for foam-breaking. Emphasis must be placed here on the fact that an information like this is difficult to find out from the existing measures such as foaminess and half-life which have been employed frequently.[8-9] Anyway, on the basis of the results shown in Fig.5, it may be concluded that liquid holdup of foam can be conveniently used also as a good measure of operating MFRD effectively, namely, as a typical measure which reflects well dynamic foaming intensity of the gas-liquid contactor which is related to hardness or ease of mechanical foam-breaking.

Results when the physical properties of foaming liquid and the gas-sparging and gas-liquid contacting types are varied or results when other types of foam-breakers are used, etc. will be discussed later.

References

1) M.J.Hall, S.D.Dickinson, R.Pritchard, and J.I.Evans,‘‘Prog. Ind. Microbiol.,’’ ed by D.J.D.Hockenhull, Churchill Livingstone, Edinburgh, London(1973), Vol.12, pp.170-234.
2) T.Sasaki,‘‘Hyomen-kōgaku Kōza, 3.Kaimen-gensho No Kiso,’’ Asakura Shoten, Tokyo(1973), pp.155-202.
3) T.Sasaki, *Kogyokagaku Zasshi*, 58, 809(1955).
4) A.Ohkawa, M.Sakagami, N.Sakai, N.Futai, and Y.Takahara, *J. Ferment. Technol.*, 56, 428(1978).
5) J.Biswas and R.Kumar, *Chem. Eng. Sci.*, 36, 1547(1981).
6) N.Futai, T.Murakami, and Y.Takahara, *J. Ferment. Technol.*, 54, 808(1976).
7) J.J.Bikerman, *Trans. Farady Soc.*, 34, 634(1938).
8) K.K.Kalischewski, W.Bumbllis, and K.Schügerl, *Eur. J. Appl. Microbiol. Biotechnol.*, 7, 21(1979).
9) M.Shiraishi, S.Horio, and K.Toyoshima, *Nippon Kagaku Kaishi*, 1983, 724.

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