QUARTERLY REPORT NO. 3

Investigation of the Effect of Coal Particle Sizes on the Interfacial and Rheological Properties of Coal-Water Slurry Fuels

CONTRACT NO.: DE-FG22-94PC94120

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REPORT PERIOD: 01/01/95 - 03/31/95

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SUMMARY

Microscopic behavior of the bubble pressure has been investigated for selected aqueous solutions. The Kruss dynamic tensiometer has been modified so that the analog pressure readings of the instrument can be digitized through a computer interface for post data processing. Measurements of peak pressure, minimum pressure, surfactant diffusion time, and dead time are presented for DDBS-soft and 1840-x aqueous solutions of surfactant concentrations of up to 1.0%. The implementation of the A-to-D data conversion also permits to examine the accuracy of the dynamic surface tension measurement which is based on the maximum bubble pressure principle.

ACCOMPLISHMENT

Modification of the Existing Kruss Tensiometer

Analog signal output from the diaphragm type pressure transducer of the Kruss tensiometer is interfaced with an A-to-D board installed in an IBM 386 PC. ATLAB data acquisition software from Data Translation Co. samples the analog signal at a rate of 0.2 kHz and digitizes them into the computer hard disk memory.

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One batch of data scanning over the specified bubble frequency range from one to ten per second requires approximately 1 MB hard disk memory capacity. A simple FORTRAN program identifies the peak voltage, minimum voltage, bubble life time, and dead time. AXUM graphic software generates final hardcopies.

Temporal History of Bubble Pressure

Figure 1 shows a temporal history of voltage readings for a typical case of 1% DDBS-soft aqueous solution. One cycle period of the curve is equivalent to the bubble life time, or the reciprocal of the bubble frequency. The bubble pressure increases as the nitrogen gas inflow makes the bubble grow and the bubble diameter decreases from the infinitely large curvature of the initially flat interface at the orifice exit. The bubble pressure increase as the bubble diameter decreases with time. The bubble pressure increases at a faster rate when a surfactant acts to reduce the surface "holding" tension. While the bubble pressure increases, the surfactant migrates to the newly created bubble surfaces. The surface is 'aged' with surfactant diffusion during the period of ascending curve, which is now called 'Diffusion time'. The bubble pressure reaches its maximum value (peak voltage) when the bubble grows to the orifice diameter.

Further growth of the bubble beyond the peak voltage increases the bubble diameter and the bubble pressure decreases first smoothly, and then the descending pressure curve becomes irregular most probably because of the geometrical distortion of the enlarged bubble. The enlarged and distorted bubble detaches from the orifice and the cycle completes at the time of the minimum voltage reading. The duration from the peak till the cycle completion does not directly influence the measurement of the maximum bubble pressure, and this time period is now called 'Dead time'.

It is our intention to examine such a detailed time history of the bubble pressure for different aqueous solutions and CWS fuels containing different

surfactants and/or different size coal particles, and to find a correlational evidence between the pressure history and the dynamic surface tension property. The current report presents the preliminary findings obtained for two different aqueous solutions of DDBS-soft and 1840-x ranging from 0 to 1.0% weight concentration.

Peak Voltage

The present experiment used two selected surfactants, DDBS-soft and 1840-x that respectively showed the best and the poorest performance among the tested five surfactants in lowering dynamic surface tension values as reported previously in the DOE Project Final Report by K. D. Kihm, Contract No. DE-FG-22-92PC92156 (1994). Figures 2-a and b respectively show the Kruss instrument results of dynamic surface tension versus the bubble frequency for the selected two aqueous solutions. The results of DDBS-soft show consistently lower dynamic surface tension values than their counterparts of 1840-x data over the surfactant concentrations and bubble frequencies considered.

The peak voltage data is directly converted to determine the dynamic surface tension. The peak voltage data obtained for DDBS-soft (Fig. 3-a) and 1840-x (Fig. 3-b) show a close similarity to the dynamic surface tension curves presented in Figs. 2-a and b. The digitized output of peak voltage provides more detailed information and more convenient scope for further data processing than the chart recorder output of dynamic surface tension values.

Minimum Voltage

Figures 4-a and b show the temporal history of minimum voltage readings for DDBS-soft and 1840-x aqueous solutions, respectively. Constant minimum voltage over the range of bubble frequencies at a given surfactant concentration shows that the system recovers to an identical initial condition before beginning of the next cycle. This also ensures the accuracy of the dynamic surface tension

measurement that assumes an identical initial condition regardless of the bubble frequency.

The minimum voltage represents the hydrostatic pressure at the depth of the gas (N_2)-liquid interface at the time of cycle completion or of new cycle initiation. The minimum voltage can decrease when the gas-liquid interface recedes from the orifice exit and stays inside the orifice at the time of cycle completion. The receding of the gas-liquid interface is likely to occur at higher surfactant concentration that enhances the solution wetting and increases the interface penetration inside the orifice. Results for both aqueous solutions (Figs. 4-a and b) show that the minimum voltage level decreases with increasing surfactant concentration.

Increase in the minimum voltage could occur when the hydrostatic pressure is higher than that at the orifice exit. This may occur as a result of an incomplete bubble detachment at the end of the cycle. The remaining undetached portion of the bubble can result in a deeper initial depth than the orifice exit and the pressure transducer will detect a higher hydrostatic pressure than it should be. This type of bias may occur at extremely high bubble frequencies where the dead time is insufficient for full recovery of the cycle with a complete bubble detachment. A high-speed synchronized cinematograph could be employed to carefully visualize the bubble growth and detachment as a future investigation.

Dead Time

Figures 5-a and b show the ratio of the dead time to the bubble life time as a function of the bubble frequency for DDBS-soft and 1840-x at different concentration levels. This ratio increases linearly with increasing bubble frequency and also increases with increasing surfactant concentration. Reduced surface tension at higher surfactant concentrations expedites the bubble growth rate and shorten the diffusion time. The dead time, which occupies the remainder of the bubble life

time, increases and the percent dead time goes up with increasing surfactant concentration for a given bubble life time.

For a fixed surfactant concentration the dead time ratio increases with the bubble frequency. This implies that the percent diffusion time decreases with increasing bubble frequencies and the surface aging by the surfactant migration is insufficiently achieved. This relatively short diffusion time at higher bubble frequencies retards a full benefit of surfactant. Larger dynamic surface tension values measured at higher bubble frequencies (see Figs. 2-a and b, for example) are attributed to the shortened diffusion time with increasing bubble frequency.

FUTURE PLAN

For the forthcoming quarter (from 04/01/95 to 06/30/95), measurements will be made for the bubble pressure characteristics including the peak voltage, minimum voltage, and dead time for CWS samples containing coal particles of different size classes. Measurements will also be carried out for CWS samples mixed with selected surfactants at different concentrations. Results will be carefully examined to find correlations of the effect of coal particle sizes on dynamic surface tension in terms of the bubble pressure-time characteristics.

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Fig. 1 Temporal history of the bubble pressure

Fig. 2-a Dynamic surface tension of aqueous solution of DDBS-soft versus the bubble frequency.

Fig. 2-b Dynamic surface tension of aqueous solution of 1840X versus the bubble frequency.

Fig. 3 Peak voltage versus bubble frequency for aqueous solutions with (a) DDBS-soft, and (b) 1840-x.

Fig. 4 Minimum voltage versus bubble frequency for aqueous solutions with (a) DDBS-soft, and (b) 1840-x.

Fig. 5 Percent dead time versus bubble frequency for aqueous solutions with (a) DDBS-soft, and (b) 1840-x.