Turbidimetric determination of particle size of disperse dye in aqueous dispersion media

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INTRODUCTION

Disperse dyes are sparingly water soluble substances, thus the dispersion properties are the significant factors that affect the dyeing of polyester fabric(e.g. stability of aqueous dispersion, dispersion behaviour, size and shape of dye particle or agglomerate, etc.).

The transparency of a dye solution is not only determined by actual absorption resulting from electron excitation but also that additional loss of light intensity occurs through light scattering on the colloidal particles. With visible spectrum of disperse dye solution, it is apparent that a large proportion of extinction of light can be attributed to light scattering.

The Mie theory of light scattering is an attractive means of determining particle size and testing dispersion of fine particles. The most common and simplest kind of light scattering technic for particle size determination is by turbidity. The turbidity τ is defined by

$$\tau = \frac{1}{\ell} \ln \frac{I_0}{I_t}, \qquad [1]$$

$$\tau = N\pi r^2 Q_{ext} \qquad [2] \qquad \text{; for monodisperse system}$$

$$\tau = \pi N \int_0^\infty r^2 \, Q_{ext} \, f(r) \, dr \qquad [3] \qquad \text{; for polydisperse system}$$

where I_0 is the incident intensity of colliminated light beam, I_t is the transmitted intensity of the beam, ℓ is the optical path length, N is the particle concentration, r is the particle radius, $f(r)$ is the particle size distribution function and Q_{ext} is the extinction coefficient which is a function of the particle size, the ratio of the refractive index of the particle(n_p) to that of the medium(n_m).

In this investigation, turbidity of disperse dyes(press cake) milled with dispersing agent during 1-25 hours were measured and the average particle size of dye particles were calculated.

EXPERIMENTAL

C.I. Disperse Blue 56, C.I. Disperse Blue 79(press cake) and anionic dispersing agent(Matexil DA-N, ICI-Woobang) were used in milling process. Milling was perform with 2㎜ glass bead and mechanical stirrer in steel beaker, the dye to dispersing agent weight ratio was 1:1. Turbidity was measured by using UV-visible spectrophotometer(Unicam 8700). The refractive index of dyes was determined by Becke's line method and Abbe Refractometer(Type 2T, ATAGO) was used. The extinction coefficient Q_{ext} was computed from the Mie theory, Eq. [4], and from the Rayleigh equation, Eq. [5].

$$Q_{ext} = \frac{2}{\alpha^2} \sum_{n=0}^{\infty} (2n+1) \times \{ |a_n|^2 + |b_n|^2 \} \qquad [4]$$

$$Q_{ext} = \frac{8}{3} \alpha^4 \left\{ \frac{m^2-1}{m^2+2} \right\}^2 \times \left\{ 1 + \frac{6}{5} \alpha^2 \left(\frac{m^2-2}{m^2+2} \right) \right\} \qquad [5]$$

where α is the dimensionless particle size, $\alpha = \frac{2\pi r}{\lambda}$, m is the relative refractive index of particle to medium, $m = \frac{n_p}{n_m}$, and in Eq. [4] a_n and b_n are complex Bessel function of α and m which was computed by using C program.

To compared with turbidimetric method, the particle size distribution of dyes were measured with laser particle size analyzer(Mastersizer, Malvern instrument).

RESULTS AND DISCUSSION

Incorporating the volume fraction Φ given by Eq. [6] into Eq. [3] and rearranging yields a dimensionless turbidity, specific turbidity, Eq. [7].

$$\Phi = \frac{4\pi N}{3} \int_0^{\infty} r^3 f(r)\, dr \qquad [6]$$

$$\frac{\tau}{\Phi} = \frac{3}{4} \frac{Q_{ext}}{r} \qquad [7]$$

$$\frac{\tau}{\Phi} = \frac{3}{4} \frac{\int_0^{\infty} r^2 Q_{ext} f(r)\, dr}{\int_0^{\infty} r^3 f(r)\, dr} = \frac{3}{4} \frac{Q_{ext}}{r_{av}} \qquad [8]$$

In monodisperse colloidal system specific turbidity could be obtained from Eq. [7], but the aqueous dispersion of disperse dye was polydisperse colloidal system. Therefore in polydispersion system specific turbidity was theoretically obtained by assuming that this system is monodisperse system. Thus, by comparing this theoretical specific turbidity with the experimentally obtained specific turbidity, the mean particle size of dye can be measured simply.

The Specific turbidity spectra of the two disperse dye were shown in Fig. 1. and Fig. 2.

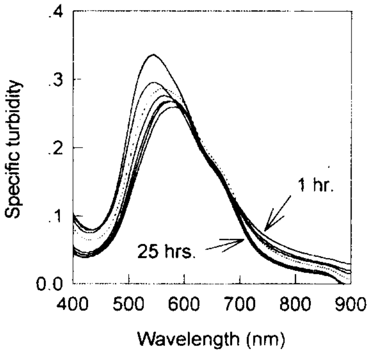

Fig. 1. Spectral specific turbidity of dispersion of C. I. Disperse Blue 56.

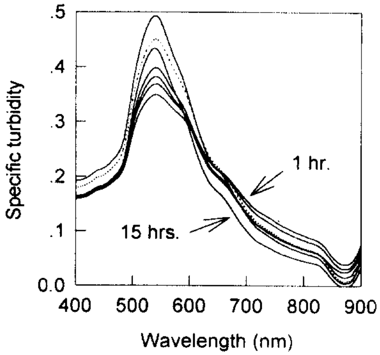

Fig. 2. Spectral specific turbidity of dispersion of C. I. Disperse Blue 79.

The mean dye particle size measured from turbidity and laser particle size analyzer, and proportion of precipitated dyes were listed in Table 1 and Table 2. The mean radius obtained from the two different method showed similar results. As milling time increase, particle size and precipitated dye reduced. These reduction represented that the stability of dispersion state was improved.

Table 1. Effect of milling time on mean particle size of C. I. Disperse Blue 56

Milling time (hour)	Specific turbidity at 850nm	Mean radius of particle (μm)		Proportion of precipitated dye (%)[b]
		From Turbidity	From PSA[a]	
1	0.039	0.046	0.045	23.6
2	0.031	0.042	0.035	18.9
3	0.029	0.041	0.030	14.7
5	0.025	0.039	0.030	6.1
10	0.018	0.036	0.030	5.4
15	0.016	0.035	0.025	4.8
20	0.016	0.035	0.025	4.9
25	0.014	0.034	0.025	4.9

[a] : measured from particle size analyzer
[b] : dye concentration : 0.06 g/l

Table 2. Effect of milling time on mean particle size of C. I. Disperse Blue 79

Milling time (hour)	Specific turbidity at 850nm	Mean radius of particle (㎛)		Proportion of precipitated dye (%)[b]
		From Turbidity	From PSA[a]	
1	0.058	0.055	0.035	18.5
2	0.056	0.054	0.035	13.6
3	0.049	0.051	0.035	9.6
4	0.038	0.038	0.030	7.5
5	0.033	0.043	0.035	6.9
6	0.029	0.041	0.035	5.3
10	0.024	0.039	0.035	4.8
15	0.015	0.034	0.035	3.7

[a] : measured from particle size analyzer
[b] : dye concentration : 0.06 g/l

CONCLUSIONS

Mean particle size of disperse dyes milled with various milling times were measured by using light transmission data. Turbidimetric method for determining particle size of disperse dye is an experimentally simple method and have a good potential for on-line application.

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