Iran.J.Chem. & Chem.Eng. Nos.10 & 11,1988. Applied Res.

DESIGN OF THICKENER BY COMPUTER

M.Edalat

College of Chemical Engineering

Sharif University of Technology

Tehran-Iran.

H.Toba

College of Chemical Engieering

Esfahan University of Technology

Isfahan Iran.

(Received 25th January,1988)

ABSTRACT

A mathematical method for calculation of the minimum cross-sectional area of a thickener is presented By obtaining minimum laboratory batch settling test data,a function, which is called settling function,is derived.This function is found to be in the form of a polynomial of third order.The settling function and mass flux relation are used for the design of thickener.The method predicts the minimum cross-sectional area of a thickener in Tehran Chemical factory where soduim sulfate is produced.The results thus obtained are promising since they are more accurate than those found through the commonly used graphical method.

INTRODUCTION

In the design of a thickener,the sedimentation principles should be considered.These principles have been first described through stocke's and Newton's equations,by assuming free falling of rigid spherical particles in a fluid under the influence of an external force such as gravity . Richardson and Zaki(1) presented a theoritical analysis of settling rates for different sizes of particles . Swanson(2) also developed a relation for settling rate covering a wide range of particle sizes.None of the above mentioned theories could be used to size a thickener.

The first comprehensive analysis of sedimentation was developed in 1916 by Coe and Clevenger (3).They showed that in a continuous unit,settling particles may pass through a number of intermediate zones.The sedimention unit must be designed for the zone exhibiting the minimum settling rate.They showed that the area of the unit could be calculated through the following equation.

$$S = 1.333(F-D)/(V-SG) \qquad 1$$

Where S is the area in ft^2/ton solid per 24hr,V is the settling rate in ft/hr , F and D are the initial and final plup dilution (weight ratio of liquids to solids) and SG is the specifie gravity of liquid phase .

In 1952,Kynch(4)presented a mathematical analysis of batch settling based on the concept that the settling velocity of a particle is only a function of the local solids concenteration.Talmadge and Fitch(5)presented a graphical method to determine the minimum thickener area in 1955.

The Design of Thickener

In the design of a thickener for

a specified quantity of slurry, the minimum cross-sectional area of the thickener which will allow passage of the solid , must be determined by specifying the solid mass flux with respect to settling velocity.

A solid material balance and an overall liquid balance around a thickener will lead to the following equation (5,6).

$$\frac{C_1L_1}{S} = \frac{V_1}{\left(\frac{1}{C_1} - \frac{1}{C_u}\right)\frac{\rho_{av}}{\rho_w}} \qquad 2$$

Where S is thickener cross-sectional area, L_1 is slurry down flow rate, C_1 is the minimum concenteration at which the boundary layer interfere , C_u is underflow concenteration of thickener, V_1 is settling velocity of the particles, ρ_{av} is average density of slurry and ρ_w is density of clear liquid. Eqn. 2 relates solid mass flux to setting velocity. The lowest value of $\frac{C_1L_1}{S}$ with respect to V_1 , $\left(\frac{C_1L_1}{S}\right)_{min}$, determines the minimum thickener cross-sectional area, S_{min}, Thus

$$\frac{\partial}{\partial V_1}\left(\frac{C_1L_1}{S}\right) = 0 \qquad 3$$

In Equation 2 C_1 is a function of V_1. The following procedure may be applied to find such a function .

The single batch setting test data which is given in table(1) fitted to a polynomial such as

$$Z_1 = \sum_{i=0}^{n} a_i t_1^i \qquad 4$$

Where a_i is evaluated by means of the least square curve fitting (7). The settling velocity V_1 is simply the derivative of equation 4 with respect to time.

$$V_1 = \frac{dz_1}{dt} = \sum_{i=0}^{n} (i+1)a_i t_1^i \qquad 5$$

The concenteration of solid, C_1 , at time t_1 corresponding to velocity V_1 is determined by a solid mass balance.

$$C_1Z_i = C_0Z_0 \qquad 6$$

Where C_0 is the initial concenteration and Z_0 is the height of slurry at t=o, and Z_i is the height which the slurry would occupy if all the solids present were at concenteration C_1. Z_i , as it is shown in Fig. (1), is the intersection point of the tangent line with the curve and the ordinate. Z_i may conveniently be expressed in terms of V_1. From Fig. (1)

$$V_1 = \frac{Z_i - Z_1}{t_1} \qquad 7$$

$$Z_i = V_1t_1 + Z_1 \qquad 8$$

substituting Eqn. 8 into Eqn. 6 gives

$$C_1 = \frac{C_0Z_0}{V_1t_1 + Z_1} \qquad 9$$

Eqns. 2 , 3 , 4 , 5 and 9 are solved simultanously by iteration method and the minimum cross-sectional area is calculated.

CONCLUSIONS

In order to find the best function representing all single batch settling data of table(1) accurately, several functions such as $Z_1 = At_1^B$, $Z_1 = Ae^{Bt_1}$ and $Z_1 = \sum_{i=0}^{n} a_i t_1^i$ are tested. The function $Z_1 = \sum_{i=0}^{3} a_i t_1^i$ gives the best result amoung the other tested functions.Table (2) shows the results of the curve fitting.Thus function $Z_1 = \sum_{i=0}^{3} a_i t_1^i$ and Eqns. 2 , 3 , 4 , 5 and 9 are solved simultanously by iteration method in order to calculate the minimum cross-sectional area of the thickener.Calculated cross-sectional area and actual cross-sectional area for the Tehran Chemical thickener are presented in table(2).The results obtained by the present method shows that this method is promising and can predict the minimum cross-sectional area more precisely.In addition,This method can predict minimum cross-sectional area of thickener without using any additional Figure and chart.A flow diagram of the calculation procedure is presented in Fig.(2)

Design Data

Z_0 = 2000 MLS
C_0 = 36.20 lb/ft^3
C_u = 52.63 lb/ft^3
ρ_{av} = 1.28 lb/ft^3
ρ_w = 1.8 lb/ft^3

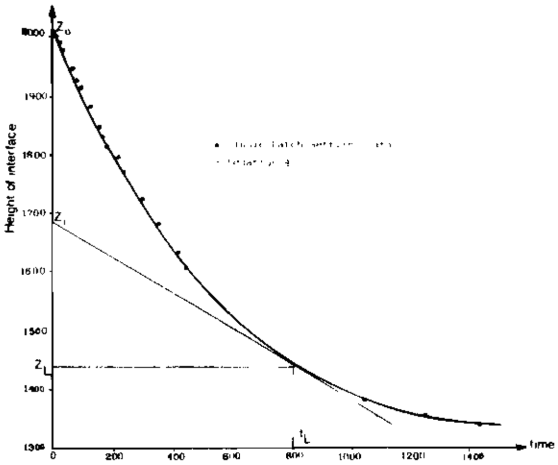

Fig.1. Hieght of interface between clear liquid and slurry with respect to time.

Table 1. Single batch settling test data.

t(min)	Z_{MLS}	t(min)	Z_{MLS}
0	2000	150	1845
5	1995	160	1875
10	1990	180	1810
15	1985	220	1790
20	1980	240	1760
25	1975	300	1715
30	1970	360	1675
45	1955	420	1625
60	1940	450	1600
75	1920	1050	1375
90	1905	1260	1350
105	1885	1320	——
120	1875	1440	1340
135	——		

Table 2- Coefficient of polynomials and thickener cross sectional area

Degree of polynomial	Variance	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	Thickner cross section area ft^2		
										Calculated	By Kynch method	Actual
3	[illegible].17	2002.64	-69.079	2.357	-0.0262	—	—	—	—	[illegible]	19905	[illegible].67
4	[illegible].49	[illegible]002.44	-68.[illegible]	2.229	-0.0205	-0.000121	—	—	—	—	—	—
5	232.07	2002.92	-69.8[illegible]	2.7[illegible]	-0.0843	0.003341	-0.000063	—	—	—	—	—
6	238.72	20[illegible]4.2[illegible]	-7[illegible].830	[illegible].053	-0.5564	0.04425	-0.001632	0.000022	—	—	—	—
7	246.39	1999.14	-51.872	-14.859	[illegible].2398	-1.00622	0.07617	-0.00269	0.000036	—	—	—

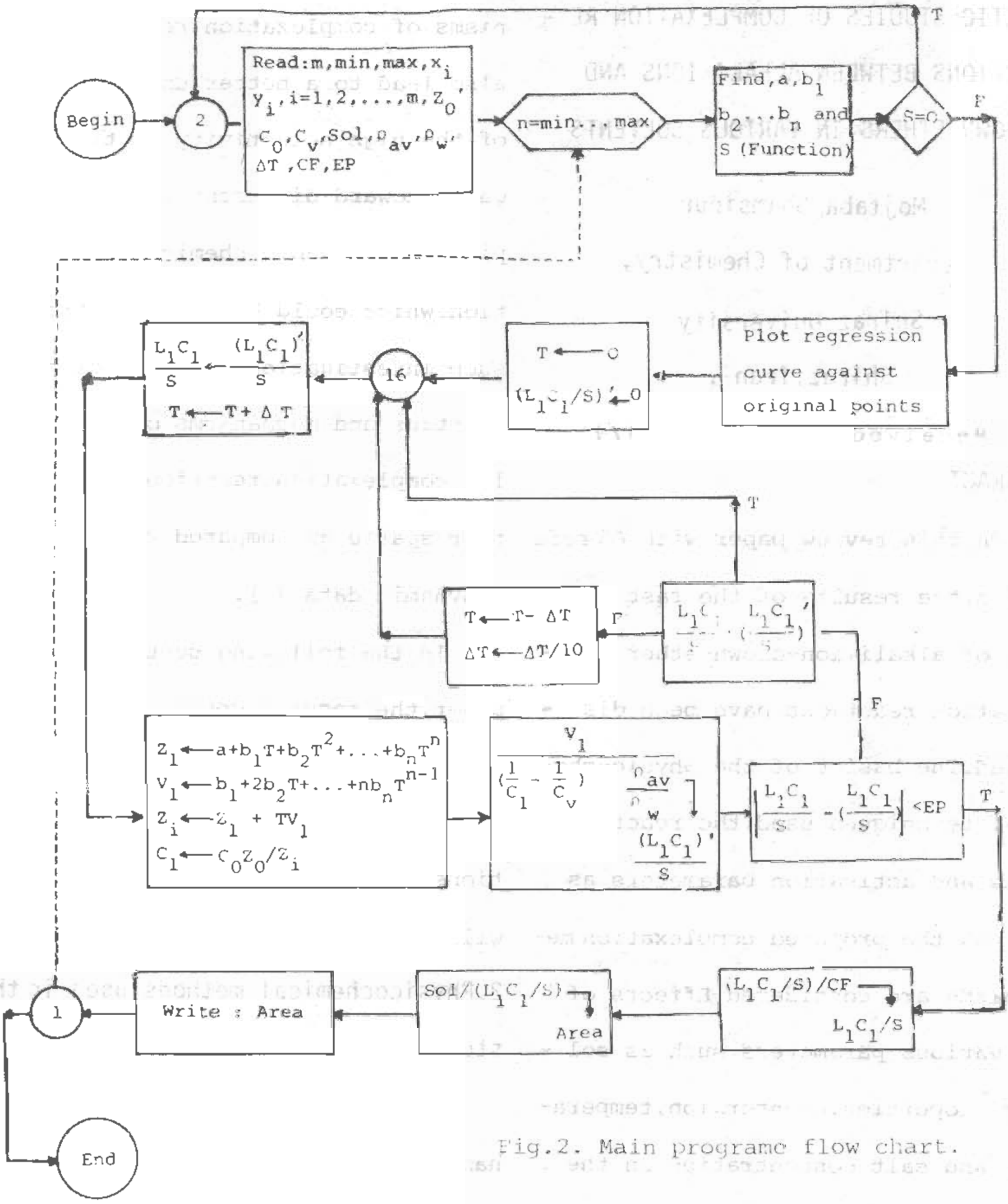

Fig.2. Main programe flow chart.

REFERENCES

1. J.F.Richardson and W.N.Zaki,"Sedimentation and Fluidization".Trans. Inst.Chem.Engns.(London) 32(1954).

2. V.F.Swanson;Trans.AIME 238,160(1967).

3. H.S.Coe,G.H.Clevenger;Trans.Inst. Mining Engrs.55,356(1916).

4. G.J.Kynch;Trans Faraday Soc. 48 , 166(1950)

5. W.L.Talmadge,E.B.Fitch;Ind. Eng . Chem.47,38(1955)

6. A.Foust,Leonard A.Wenzel, Curtis W.Clump,Louis Maus,L.Bryce Anderson,"Principles of Unit Operation John Wiley & Son Inc.(1960)

7. B.Carnahan,H.A.Luther,J.O.Wilkes, "Applied Numerical Methods" John Wiley & Son Inc.(1969)