A METHOD FOR EVALUATING SEED BALANCE PARAMETERS IN ALUMINA REFINERY SEED CLASSIFICATION SYSTEMS

Walter M. Bounds, Jr.
2583 Woodland Ridge Blvd.
Baton Rouge, LA 70816
Bounds_W@msn.com

Abstract

An important consideration in controlling alumina refinery seed classification systems is ensuring that quantity and particle size distribution for seed produced matches with that for seed charged. When this condition is not satisfied, the system may not be stable, resulting in changing seed inventory quantities and particle size distribution. In this paper, information from a previously reported method for evaluating operating characteristics of seed classifiers is utilized to simulate a classification system and determine seed charge quantities and particle size distribution which balance with seed produced. Out-of-balance cases are described to evaluate consequences, and balanced cases are developed to illustrate the method.

Introduction

A typical Bayer Process alumina refinery involves precipitating alumina tri-hydrate from a caustic solution. In order to accelerate the precipitation process to commercially feasible rates, previously precipitated alumina tri-hydrate is added to the pregnant solution. This "seed" material forms sites for the crystals to form. The entire mass of solids resulting from the precipitation process is then separated into either product material which is forwarded, or fresh seed to be recycled back to the crystallizing equipment. The forwarded product material is taken out and either dried to form alumina tri-hydrate product or calcined to reduction grade alumina. The seed material is often separated into a coarse fraction and a fine fraction before recycling to the precipitators. Since the quantity of seed used can be much larger than the net product, managing the inventory of seed can be of critical importance. With a limited total volume of equipment available, increasing volume used for seed storage can encroach on volume used for precipitation, thus reducing volume available for precipitation and affecting processing rates. Alternatively, decreasing seed inventory can result in insufficient seed material for recycle to the precipitators, also affecting processing rates. Clearly then, controlling seed inventory is vital to proper operation of an alumina refinery, and the activities and operations associated with controlling seed inventory are referred to as "seed balance".

Seed classifiers are the principal unit operations involved in seed balance activities, and a method for evaluating operating parameters for seed classifiers has been reported earlier (1,2). The purpose of this paper is to describe results from using this method to evaluate parameters associated with seed balance in an alumina refinery.

Single Pass Simulation

The starting point for this analysis is with the combined mass of solids after precipitation has taken place. For simulation purposes, this mass is hypothetically divided into three portions: portion A represents the net newly precipitated product; portion B represents the fine (TT) seed used in the original charge; portion C represents the coarse (ST) seed used in the original charge. These streams are then mixed to form the feed stream to the classifiers. In real world applications, other streams are also present at this point, and could be included, but omitted here to simplify the analysis. Figure 1 gives a schematic for the single pass simulation, i.e. without seed recycle.

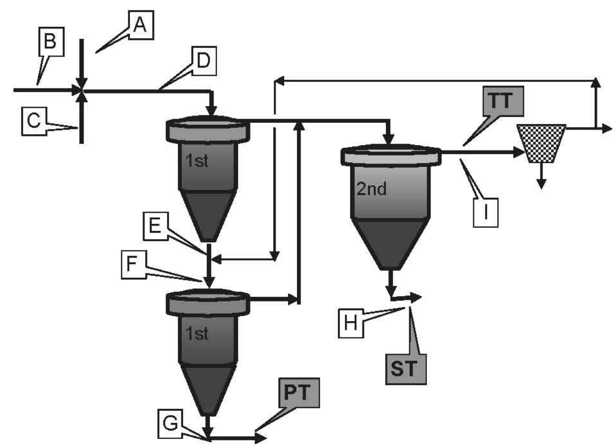

Figure 1 – Schematic for single pass simulation

Typically the classification stages are referred to as primary, secondary and tertiary. Streams A, B, and C are as described above. Stream D is the mixed stream feeding the first stage primary classifier. The thickened solids from the primary classifiers are called "PT" solids, and from the secondary classifier are called "ST" solids. The overflows from the first and second stage primary classifiers feed the secondary classifier. The overflow from the secondary classifier contains fine solids fed to a tertiary thickener represented by the small box. Typically little or no classification takes place in the tertiary, so TT solids composition is represented in secondary overflow as well as tertiary underflow. Note that first stage primary underflow, stream E, is diluted with solids free tertiary overflow to give stream F. Stream G contains the thickened coarse PT solids produced, stream H contains the thickened, coarse ST solids produced, and stream I contains the TT solids in a dilute form.

For the single pass simulation, values for streams A, B, and C are assumed, and the remaining streams calculated using the methods from (1). Vessel geometry can be allowed to vary as appropriate for a given study. The objective of the calculation would be to determine the geometry required such that the product streams G, H, and I match in quantity and particle size distribution with streams A, C and B respectively, thereby achieving a balanced seed system, i.e. seed produced matches with seed used.

Table 1 – Single pass simulation results with higher secondary flow

	A	B	C	D	E	F	G	H	I
Case 1	Primary Feed = 5.5 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.129	0.258	0.12	0.279	1.13
Solids, gpl	120	667	444	228.6	600	300	600	600	71.1
% Coarse	70	10	65	55.4	68.5	68.5	72.6	65.3	19.3
% Fine	2	50	10	15.3	5.91	5.91	5.17	7.83	40.1
Case 2	Primary Feed = 4 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.333	0.667	0.31	0.198	1.226
Solids, gpl	120	667	444	228.6	600	300	600	358	51.6
% Coarse	70	10	65	55.4	69.7	69.7	73.9	47.4	9.93
% Fine	2	50	10	15.3	7.39	7.39	6.44	8.86	48.8
Case 3	Primary Feed = 3 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.407	0.814	0.378	0.081	1.347
Solids, gpl	120	667	444	228.6	600	300	600	359	47.9
% Coarse	70	10	65	55.4	66.5	66.5	70.9	39.6	8.45
% Fine	2	50	10	15.3	8.98	8.98	7.79	6.44	45.8

Table 2 – Single pass simulation results with lower secondary flow

	A	B	C	D	E	F	G	H	I
Case 4	Primary Feed = 5.5 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.129	0.258	0.12	0.358	1.05
Solids, gpl	120	667	444	228.6	600	300	600	600	31.7
% Coarse	70	10	65	55.4	68.5	68.5	72.6	57.4	5.2
% Fine	2	50	10	15.3	5.91	5.91	5.17	11.9	59.5
Case 5	Primary Feed = 4 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.333	0.667	0.31	0.205	1.22
Solids, gpl	120	667	444	228.6	600	300	600	500	26
% Coarse	70	10	65	55.4	69.7	69.7	73.9	38.5	1.6
% Fine	2	50	10	15.3	7.39	7.39	6.44	11	81.7
Case 6	Primary Feed = 3 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.1	0.3	1.4	0.407	0.814	0.378	0.204	1.22
Solids, gpl	120	667	444	228.6	600	300	600	322	22.8
% Coarse	70	10	65	55.4	66.5	66.5	70.9	25.6	0.79
% Fine	2	50	10	15.3	8.98	8.98	7.79	11.8	84.6

Tables 1 and 2 give calculation results for the simulation described in Figure 1. Six cases are examined with varying geometry and constant values for Streams A, B, and C. Note that a fairly coarse precipitation product is assumed at 70% coarse (%+200 mesh) and 2% fine (%-325 mesh). The fine and coarse seed charge to produce that product is assumed to be 10% coarse, 50% fine and 65% coarse, 10% fine respectively. Note that the simulation does not include the precipitation process. Seed charges to produce a given product must be established by other methods. Geometry is varied such that the primary feed flow per unit of cross section varies from 3 GPM/SF to 5.5 GPM/SF, and the secondary feed flow per unit of cross section varies from 1.5 GPM/SF to 3 GPM/SF.

One very important result is that in all six cases the primary classifier underflow is much finer than the net product, stream A. The implication is that, *for this configuration, the coarse material produced in precipitation cannot be removed in classification*, and the system is destined to be out of balance. Indications of the degree of out of balance are shown in the graphs below.

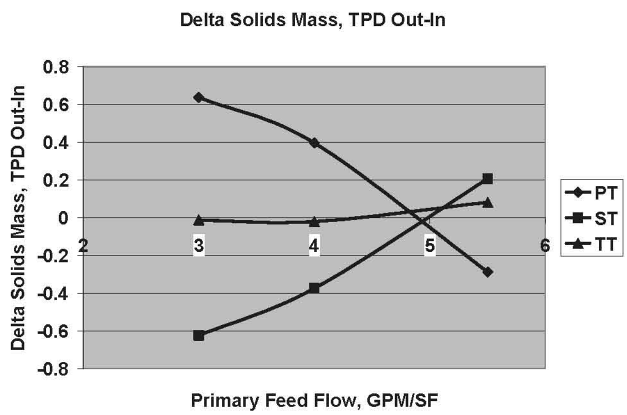

Figure 2 – Overall mass balance for single pass cases 1,2 and 3

Figure 2 shows the mass change for PT, ST and TT solids between feed and product streams for cases 1,2 and 3. For these cases, first stage primary classifier cross-sectional area is varied to allow feed to vary from 3 GPM/SF to 5.5 GPM/SF. Second stage primary cross section is adjusted to maintain 2 GPM/SF feed for all six cases. Secondary classifier cross section is adjusted to maintain 3 GPM/SF feed in cases 1,2 and 3, and 1.5 GPM/SF in cases 4,5 and 6. At the lower flowrates, solids are held up in the primary, resulting in a severe imbalance with ST solids. As the flowrate increases, this imbalance is reduced to practically nil at near 5 GPM/SF, but then diverges in the opposite direction. The TT solids remain close to balanced, except at high flowrates.

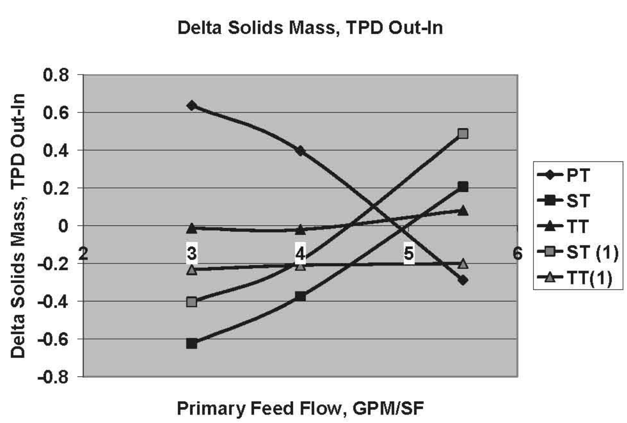

Figure 3 – Effect of reducing secondary flow on total solids balance.

Figure 3 shows the results for cases 4,5 and 6 on the curves labeled ST (1) and TT (1). The balance in PT solids is not changed when the secondary flow is reduced, but the split between ST and TT is altered significantly. Essentially, ST quantity is increased at the expense of TT quantity.

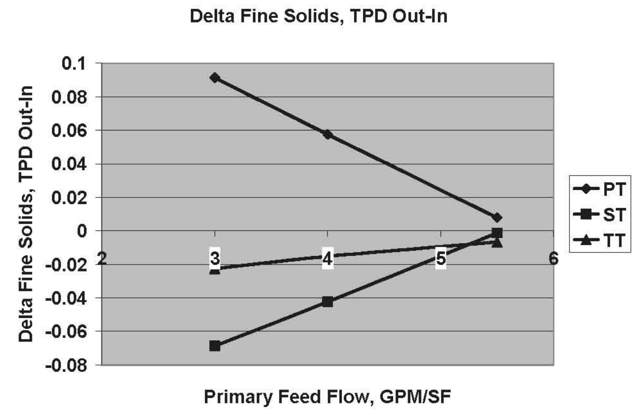

Figure 4 – Balance on fine solids only for single pass cases 1,2 and 3

Figure 4 gives the mass change for fine solids (-325 mesh) for cases 1,2 and 3. At low flowrates, excessive fine solids are distributed to the PT product and depleted from ST and TT product. The fine solids are more in balance at the higher flowrates.

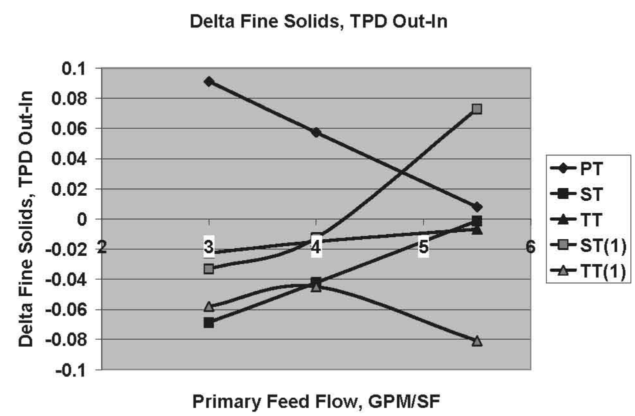

Figure 5 – Effect of reducing secondary flow on fine solids balance.

Figure 5 shows that reducing secondary flowrate shifts fine solids out of TT and into ST. Once again, reducing secondary flow has no effect on primary result.

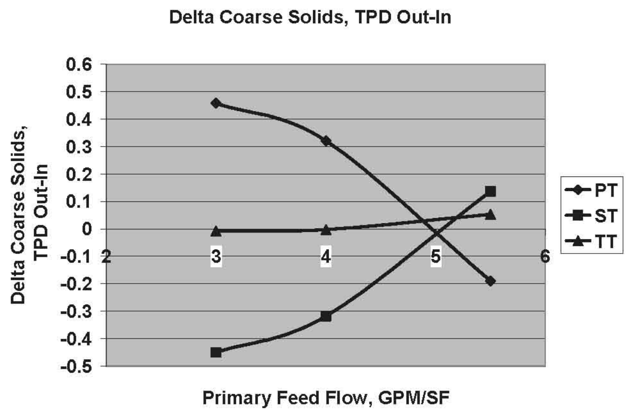

Figure 6 – Balance on coarse solids only for cases 1,2 and 3.

Figure 6 shows that coarse solids are distributed to PT solids at the expense of ST solids at low primary flowrates, and shift toward the opposite as primary flowrate increases.

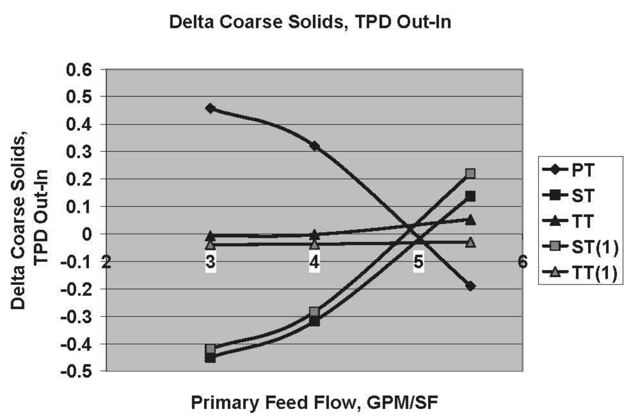

Figure 7 – Effect of reducing secondary flow on coarse solids distribution.

Figure 7 shows that reducing secondary flowrate shifts coarse solids from TT to ST. This effect is important in terms of preventing coarse material from entering tertiary thickeners. As before, reducing secondary flow has no effect on primary.

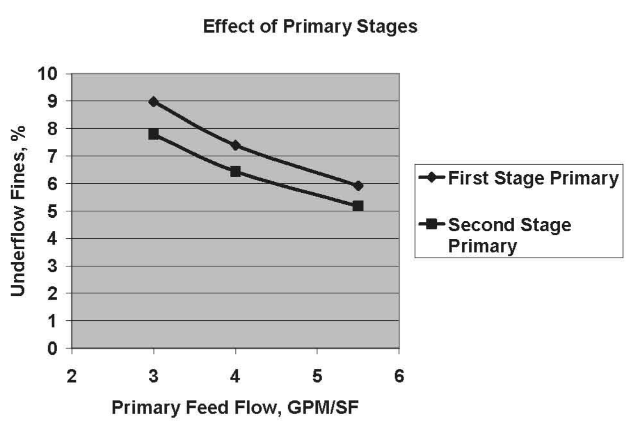

Figure 8 – Additional primary stage reduces PT fines

Figure 8 gives the change in fines concentration from the first stage primary to the second stage primary. Clearly adding primary stages with intermediate dilution can give reduced fines concentration.

Equilibrium Balanced Simulation

The equilibrium balanced simulation is a continuation of the single pass calculation. A thickener is added to the secondary underflow to give constant solids concentration, and the calculation is repeated using the produced seed streams as feed streams, as shown in Figure 9.

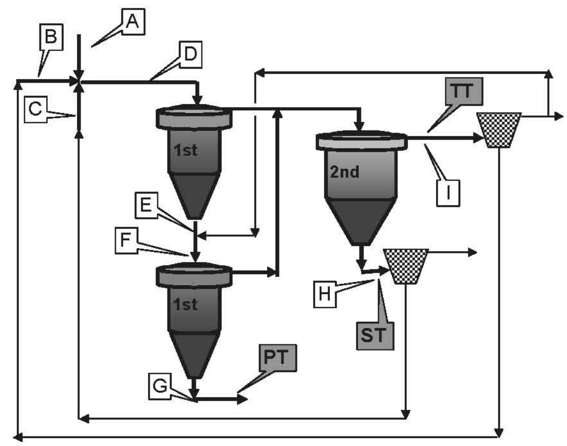

Figure 9 – Schematic for equilibrium balanced simulation

On each iteration, new product seed streams are generated and again re-introduced as feed. This calculation procedure is continued until the calculated product streams match sufficiently close with the streams fed. Iteration convergence was obtained to 0.0001 without difficulty. *The resulting seed streams generated are a perfect balance solution for a particular classifier geometry and net precipitation product stream A.* The streams are balanced for mass flow and particle size distribution. Calculation results for six cases are shown in Table 3 and Table 4, and shown graphically in Figures 10 through 16.

Table 3 – Equilibrium balanced simulation results with higher secondary flow.

	A	B	C	D	E	F	G	H	I
Case 1	Primary Feed = 5.5 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.088	0.207	1.29	0.213	0.427	0.2	0.209	1.1
Solids, gpl	120	606	606	230.5	600	300	600	600	48.3
% Coarse	70	5.69	48.3	49.5	66.2	66.2	70	48.3	5.69
% Fine	2	19.2	2.96	5.46	2.26	2.26	2	2.96	19.2
Case 2	Primary Feed = 4 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.0428	0.097	1.14	0.214	0.427	0.2	0.195	0.96
Solids, gpl	120	606	606	179.6	600	300	600	302.6	26.9
% Coarse	70	1.49	30.3	49.9	66.2	66.2	70	30.3	1.49
% Fine	2	25.7	4.21	5.63	2.26	2.26	2	4.21	25.7
Case 3	Primary Feed = 3 GPM/SF			Secondary Feed = 3 GPM/SF					
Total Flow, gpm	1	0.0272	0.061	1.09	0.214	0.427	0.2	0.186	0.92
Solids, gpl	120	606	606	159.3	600	300	600	197.8	18
% Coarse	70	0.701	22.1	53.2	66.2	66.2	70	22.1	0.702
% Fine	2	27.7	4.56	4.99	2.26	2.26	2	4.56	27.7

Table 4 – Equilibrium balanced simulation results with lower secondary flow.

	A	B	C	D	E	F	G	H	I
Case 1	Primary Feed = 5.5 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.036	0.259	1.29	0.214	0.427	0.2	0.261	1.05
Solids, gpl	120	606	606	230.5	600	300	600	600	20.9
% Coarse	70	0.77	40.5	49.5	66.2	66.2	70	40.5	0.77
% Fine	2	29	4.81	5.46	2.26	2.26	2	4.81	29
Case 2	Primary Feed = 4 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.023	0.117	1.14	0.214	0.427	0.2	0.121	1.03
Solids, gpl	120	606	606	179.6	600	300	600	584.5	13.5
% Coarse	70	0.13	25.7	49.9	66.2	66.2	70	25.7	0.13
% Fine	2	42.3	4.53	5.63	2.26	2.26	2	4.53	42.3
Case 3	Primary Feed = 3 GPM/SF			Secondary Feed = 1.5 GPM/SF					
Total Flow, gpm	1	0.015	0.073	1.09	0.214	0.427	0.2	0.119	0.98
Solids, gpl	120	606	606	159.3	600	300	600	373.1	9.1
% Coarse	70	0.03	18.6	53.2	66.2	66.2	70	18.6	0.03
% Fine	2	45.5	4.95	4.99	2.26	2.26	2	4.95	45.5

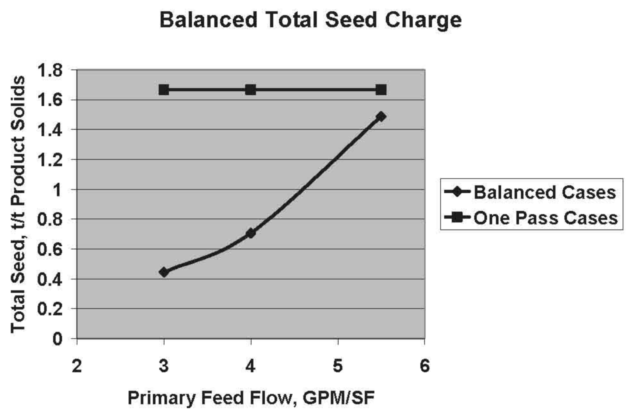

Figure 10 – Total seed for equilibrium balanced cases compared with single pass case feed.

Figure 10 shows the total seed (ST+TT) calculated from the equilibrium balanced simulation contrasted with the feed (ST+TT) in the single (one) pass simulation, vs. primary classifier geometry. Clearly the higher unit flows (smaller diameter) will allow a higher seed flow and still remain balanced.

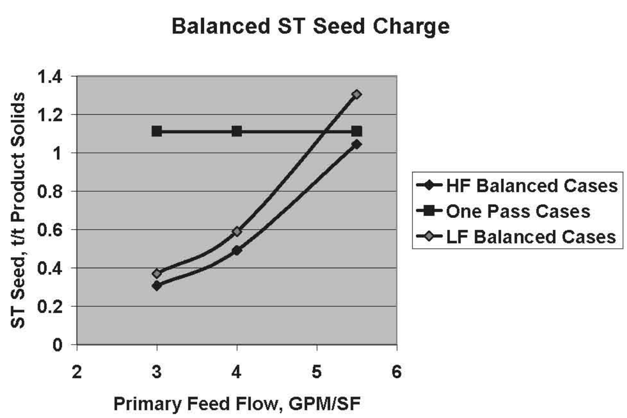

Figure 11 – ST seed for equilibrium balanced cases compared with single pass case feed.

Figure 11 shows the ST seed flow calculated for the equilibrium balanced cases (HF = high secondary flow, LF = low secondary flow) contrasted with the single (one) pass simulation feed stream, vs. primary classifier geometry.

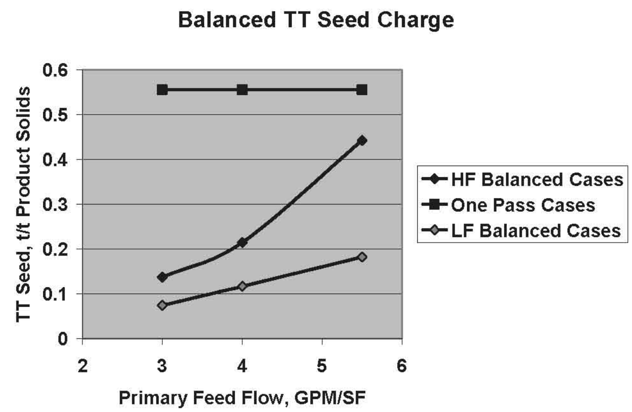

Figure 12 – TT seed for equilibrium balanced cases compared with single pass case feed.

Figure 12 shows the TT seed flow calculated for the equilibrium balanced cases (HF = high secondary flow, LF = low secondary flow) contrasted with the single (one) pass simulation feed stream, vs. primary classifier geometry.

Figures 13 through 16 show the ST and TT coarse and fine composition for the equilibrium balanced cases compared with the single pass case feed streams.

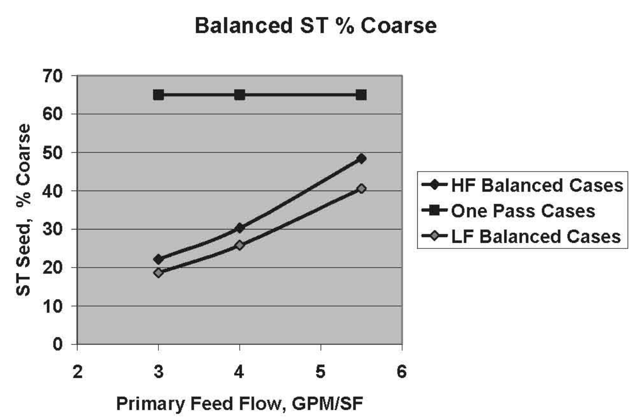

Figure 13 – ST % coarse for equilibrium balanced cases compared with single pass case feed.

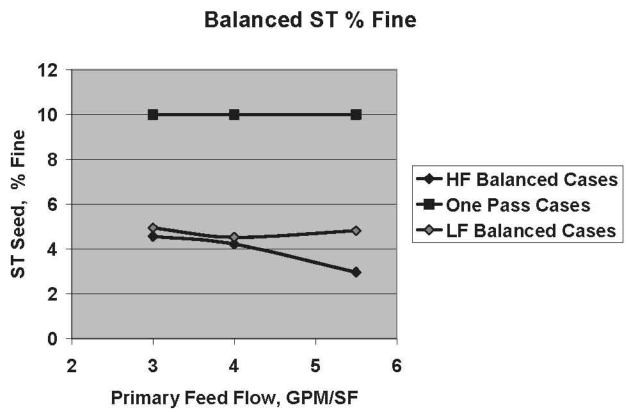

Figure 14 – ST % fine for equilibrium balanced cases compared with single pass case feed.

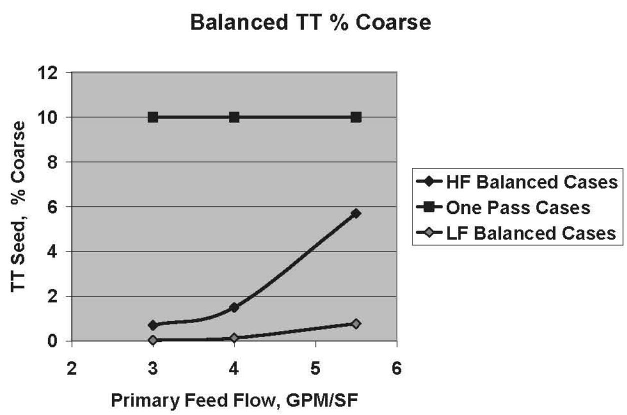

Figure 15 – TT % coarse for equilibrium balance cases compared with single pass case feed.

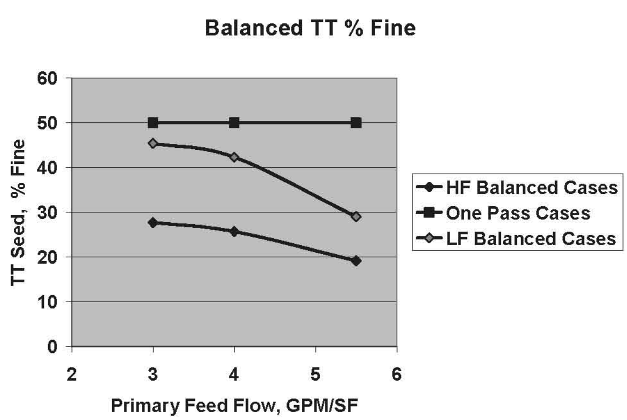

Figure 16 – TT % fine for equilibrium balanced cases compared with single pass case feed.

Precipitation net product, stream A, and vessel geometry for the equilibrium balanced cases are the same as with the single pass simulation. Note that, in the equilibrium balanced simulation, the precipitation net product is repeated exactly in the PT solids. Note also that the ST and TT solids are in perfect balance with feed streams. The variation from case to case is with the seed mass flow and particle size distribution. *The equilibrium balanced simulation method gives the seed mass flow and particle size distribution that will give perfect seed balance for a given precipitation net product and classifier geometry.* It is important to note, however, that calculated values for seed flow and composition are assumed to yield the feed stream net product in precipitation, and this analysis allows no verification of that assumption.

Conclusions

Two calculation methods are presented for analyzing seed balance in alumina refineries. Each method begins with total solids mass *after* precipitation, which allows the analysis of classification to be considered separately from precipitation. A single pass simulation gives classification product streams vs. classifier geometry for a given precipitation net product and assumed seed charges. An equilibrium balanced simulation gives the seed charge quantities and particle size distributions such that seed charge and classifier product are perfectly balanced

For the cases considered, the single pass method did not arrive at a system geometry which yielded a balanced system. However, it is the author's opinion that examination of other configurations (not considered in this paper) could lead to cases closer to balance.

The equilibrium balance method yielded seed flow and composition which allowed perfect balance in each case. It is important to note, however, that calculated values for seed flow and composition are assumed to yield the feed stream net product in precipitation, and this analysis allows no verification of that assumption.

In considering the results from both the single pass and equilibrium balance methods, an important conclusion is that classification configuration must be synchronized with precipitation seed requirements in order to achieve a balanced result. The single pass example shows clearly that for a given classifier configuration, seed balance is not achieved with some seed charges. In addition, the equilibrium balance example gives the seed charges that will achieve balance with a particular classifier configuration. A synchronized system is obtained when actual precipitation seed requirements are identical to the equilibrium balance result.

References

1. Walter M. Bounds, "A Mathematical Model for Solids Settling" Light Metals 2001. (2001), 65-69
2. Walter M. Bounds, "A Method for Evaluating Operating Parameters of Alumina Refinery Seed Classifiers Using A Mathematical Model for Solids Settling" Light Metals 2002. (2002), 153-156