To: [redacted]

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Subject: Determination of Time Until Line Slowdown Due to Low Hopper Levels

Abstract

The polymer team aims to create an improved system for estimating time until line slowdown for referencing in the event of a pulp feed maintenance stoppage. Currently, operators, mechanics and engineers have relied on a heuristic derived from only the premix hopper level (relayed from the control center) to estimate the time allotted before a line slowdown is required. Statistically, this heuristic will hold true the majority of the time, but has the potential to be misrepresentative under certain conditions. The reason for this misrepresentation is because the time until slowdown, t_{sd}, is a function of hopper level and line speed (accumulation minus output), and hopper level is a function of the premix sequence (input). Simply put, because each premix hopper's inlet flow is a semi-batch process, our current heuristic for determining time until slowdown based on a steady state process has the potential to be invalid over some non-zero percentage of the time.

Methodology

Overview

The unsteady state mass balance of the hopper is given below.

$$\left(Main\ Sequence\ Discharge\ to\ Hopper\right)_{in} - \left(Hopper\ \bar{O}utput\text{EQ}\backslash\text{x}\backslash\text{to(Hopper Output) EQ}\backslash\text{x}\backslash\text{to(WHopper Output,) }\right)_{out} = \left(Hopper\ Level\right)_{accumulation}$$

Hopper output is a function of dope rate (proportional to line speed) which varies predictably based on a user defined set point and can be considered stable. Overbar denotes steady state variable.

The main sequence discharge to the hopper is a semi-batch process in that its contribution is periodic rather than constant. The main sequence consists of seventeen steps totaling approximately 30 minutes for every sequence period. Thus, estimating time until slowdown on hopper level alone has the potential to be around a half an hour off in the case where the main sequence discharge sequence is in a step farthest away from the discharge step (step 15).

A display showing each step in the sequence is given below.

DONE	STEP	ACTION	ELAPSED TIME
✓	1	INTIATE BATCH.	00 : 00
✓	2	CHECK SYSTEM STATUS.	00 : 00
✓	3	LOAD BATCH RECIPE PARAMETERS.	00 : 00
✓	4	START AO SEQ. START BASIS WGT STANDARDIZATION.	00 : 00
✓	5	START PULP SCANNING. INTIATE INHIBITOR SEQUENCE.	00 : 02
✓	6	START PREMIXER MAIN DRIVE.	00 : 00
✓	7	NOT USED.	00 : 00
✓	8	WAIT FOR SUBSEQUENCES TO BE COMPLETE.	01 : 07
✓	9	START PULP FEED SEQUENCE.	00 : 00
✓	10	WAIT FOR PULP FEED SEQUENCE TO COMPLETE.	06 : 47
✓	11	START PREMIXER SEAL PUMP.	00 : 00
✓	12	START PREMIXER CHOPPERS.	00 : 00
	13	**TIMED PREMIX.**	04 : 42
	14	CALCULATE TOTAL BATCH WEIGHT.	09 : 06
	15	DISCHARGE BATCH TO PREMIX HOPPER.	01 : 59
	16	CLOSE DISCHARGE VALVE ON PREMIXER.	00 : 12
	17	SHUT DOWN PREMIXER MAIN DRIVE.	00 : 10

A couple of problems surface when attempting to identify a trend time for each step in the sequence. One can't just average elapsed time data from PIMS over a given period of time (say six months) for each step to determine that step's effect on t_{ds} because there exists variances in specific steps that are too random and/or involve many other functions that would be too complex to model for an unproportioned return on investment. For example, trend data suggest that step one can vary from zero minutes to ten minutes due to operator involvement (shutdown, alarm etc.) and would be too random to model in an effective way. Another example is that the AO sequence is shared between streams and modeling a potential delay in step four would involve a complex transfer function with another stream.

For these reasons, the outliers of each trend data set have been omitted from the average time per step calculation. Scrupulous engineers, in audit of the proposed system, should be advised that this model holds functional accuracy insofar as these outliers do not increase in duration or occurrence. Relevant parties should be aware of any active alarms to minimize the effect of step delays unaccounted for.

Application

Knowing the mass flow out of the hopper derived from the line speed and subtracting the time factor of the main sequence, the time until slowdown, t_{sd}, can be found.

$$t_{sd} = t_{ihl} - t_{ms}$$

$$t_{ihl} = time\ until\ slowdown\ for\ the\ instaneous\ hopper\ level$$

$$t_{ms} = time\ factor\ of\ the\ main\ sequence$$

By defining a lower hopper level that would require a slowdown, the time until slowdown for the instantaneous hopper level,t_{ihl}, can be solved for in the equation below.

$$t_{ihl} = \frac{m_{hl} - m_{sd}}{\dot{m}_{dr}}$$

$$m_{hl} = current\ hopper\ level\ (lbs)$$

$$m_{sd} = hopper\ level\ requiring\ a\ slowdown\ \ (lbs)$$

$$\dot{m}_{dr} = current\ dope\ rate\ output\ \ (\frac{lbs}{hr})$$

The time factor of the main sequence can be found on Table B, given below, when the current main sequence step is known. Table A, below, gives values for t_{ihl} for a range of current hopper levels and dope rates. The time until slowdown equation will be simplified with simple variable symbols coordinated with each table for ease of implementation.

$$t = A - B$$

Results and Discussion

Any person advised to use this approximation method should be aware of the following notes and disclaimers.

i. The purpose of this method is to approximate the time allowed for maintenance and repair upstream of the premix hopper before a slowdown is imminent. For many (possibly most) scenarios, it is the maintenance personal that specifies a time required for a certain job and the control center responds accordingly. Thus, often, it is the current dope rate that is a function of required maintenance time and not the other way around. This approximation method is best used as an education tool or to give a reference point for new control center personal or green hat engineers (the author).

$$f(maintenance\ time\ required) = (Time\ Before\ \ Slowdown\ at\ Current\ Dope\ Rate)$$

ii. This preliminary model uses the variable, m_{sd}, the hopper level that, once reached, requires a line slowdown, in attempt to keep the mathematics simple. The problem with this variable is that is attempts to quantify a value that should be optimized based on rates. Simply put, the actual value of m_{sd} should equal zero and time should be optimized to maximize the time at the current dope rate AND the overall time until the hopper level goes to zero.

An advanced model will optimize for the maximum time until rate change, t_{sd}, under the parameters of maximizing the area under the current dope rate curve AND the sum of the areas under the current dope rate curve and the slowdown rate curve.

```
function y= (t_sd)

maximize value {∫_0^{t_sd} (current dope rate) dt}

   parameter

         maximize
value{∫_0^{t_sd} (current dope rate) dt + ∫_{t_sd}^{t_f} (slowdown rate) dt}

         a = ∫_{t_sd}^{t_f} (slowdown rate) dt

         a = constant value defined by set slowdown rate

         end

end
```

$$\max \; \text{value} \left\{ \int_0^{t_{sd}} (current\ dope\ rate)\,dt \right\}$$

$$\max \; \text{value} \left\{ \int_0^{t_{sd}} (current\ dope\ rate)\,dt + \int_{t_{sd}}^{t_f} (slowdown\ rate)\,dt \right\}$$

$$a = \int_{t_{sd}}^{t_f} (slowdown\ rate)\,dt$$

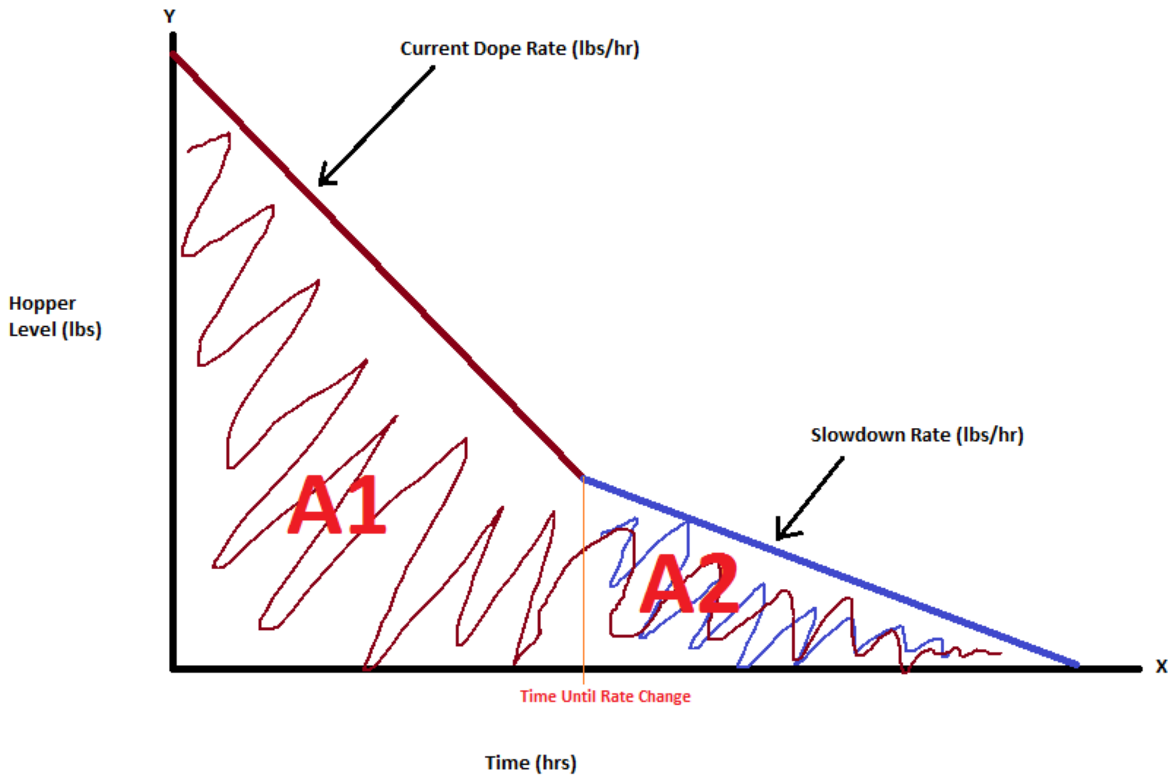

Figure 1. Plot of Hopper Level vs Time For No Inlet Flow Conditions. An advanced model will optimize the time until rate change, t_{sd}, maximizing for A_1 and (A_1+A_2).

iii. Any personal advised to use this approximation method should be aware of when the model fails and when it should be updated for a particular situation. Be aware that the hopper level requiring a slowdown, m_{sd}, has historically varied for all operators in the control center based on intuition and experience. As stated before, any significant changes to the main sequence should be applied to update the model as well. All changes can easily be made in the referenced excel spreadsheet.