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Informal Note #9

AN ADVANCED RETARDER CONTROL ALGORITHM: PRELIMINARY CONCEPT DESIGN III

BACKGROUND

Herein we shall try to implement an approximate headway control algorithm similar to that outlined in Note 6, using some of the energy formulas described in Note 7. We use the same notation displayed in Figure 1.

ALGORITHM

The algorithm is an iterative search procedure in which the highest retarder exit velocity for the second car, V_{22}, is calculated, subject to the constraint that sufficient headway exists at the point of switching. The highest release velocity is desired since this maximizes hump throughput. The algorithm is described with the following steps.

Step 1: Calculate V_{13} and T_{13}

The two cars will be switched to two different routes at a distance x from the end of the retarder. The drop in elevation at x from the end of the retarder is h; the value of h is stored in a table for each switch. The retarder exit velocity of the first car (V_{12}) and its exit time (T_{12}) are measured. The values of V_{13} and T_{13} are calculated from the following equations*:

(1) $\frac{V_{13}^2}{2g} = \frac{V_{12}^2}{2g} + [h - R_1 \cdot x]$, and

(2) $T_{13} = T_{12} + \frac{2 \cdot x}{V_{12} + V_{13}}$

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*R_1 is the rolling resistance of the first car.

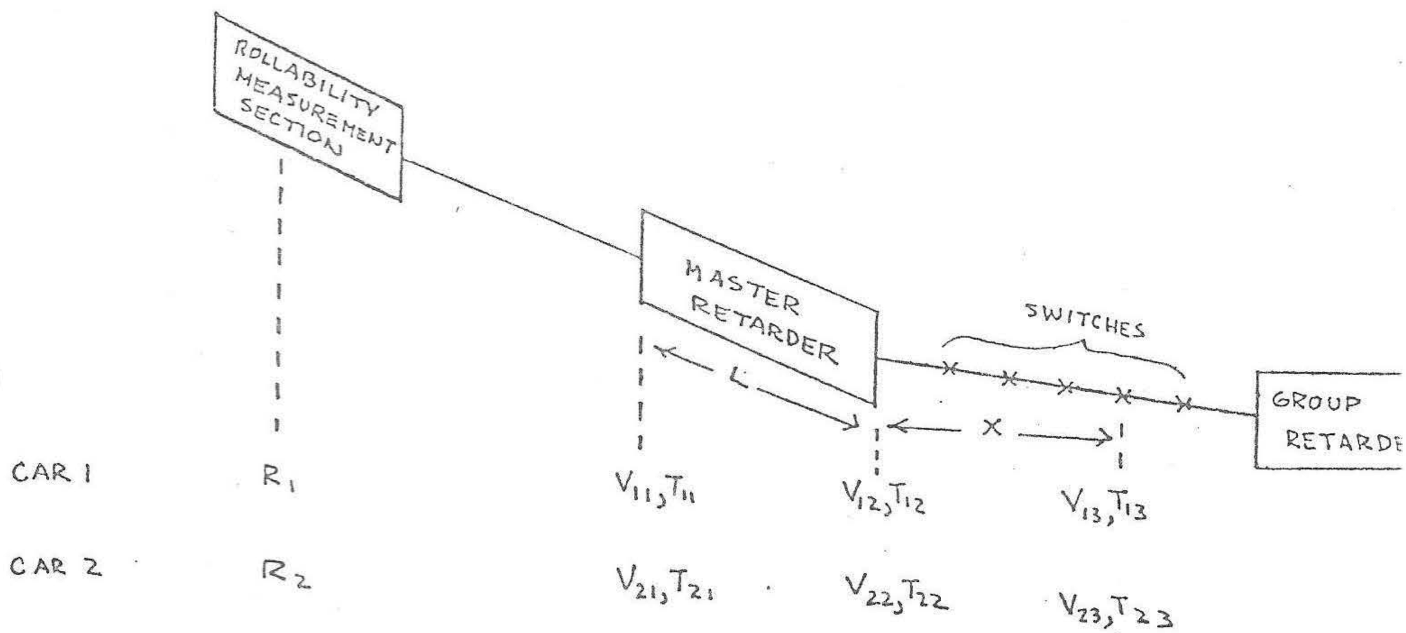

FIG. 1: INFORMATION PERTINENT TO CONTROL OF MASTER RETARDER

where V_{13} in (2) is calculated in (1).

Step 2: Assume a Large Initial V_{22} and Calculate T_{22}, V_{23}, and T_{23}

The retarder entrance velocity of the second car (V_{21}) and its entrance time (T_{21}) are measured. The values of T_{22}, V_{23}, and T_{23} are calculated for an assumed large initial value of V_{22} using the following equations:

$$(3) \quad T_{22} = T_{21} + \frac{2 \cdot L}{V_{21} + V_{22}}$$

where L is the length of the retarder,

$$(4) \quad \frac{V_{23}^2}{2g} = \frac{V_{22}^2}{2g} + [h - R_2 \cdot x]^* \text{ , and}$$

$$(5) \quad T_{23} = T_{22} + \frac{2 \cdot x}{V_{22} + V_{23}}$$

where T_{22} in (5) is calculated in (3) and V_{23} in (5) is calculated in (4).

Step 3: Calculate Headway at Point of Switching

The headway at point of switching is given by:

$$(6) \quad \text{Headway} = (T_{13} - T_{23}) \cdot \left[\frac{V_{13} + V_{23}}{2}\right] - \quad (\text{length of first car}^{**}).$$

Step 4: Try Lower Value of V_{22} if Headway Too Small

If headway given in (6) is too small, then Steps 2 and 3 are repeated with the assumed value for V_{22} decreased by a constant Δ. We keep decrementing V_{22} by an amount Δ until the headway constraint in (6) is satisfied.

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*R_2 is the rolling resistance of the second car.

**The length of the first car can be a measured value, or taken from waybill data, or an assumed average car length.

REMARKS

In (2) and (5), the time a car takes to reach the switching point x, is calculated as the distance x divided by the average velocity over the car's run. The average velocity over the car's run is approximated by averaging the two velocities at the beginning and end of the run for car i:

$$(7) \qquad \text{Average Velocity} \cong \frac{V_{i2} + V_{i3}}{2}$$

If there is a constant grade over the distance x, then (7) is accurate. However, if the grade changes then (7) is only approximate. The approximation in (7) can be improved by defining an experimentally determined fudge-factor K, so that:

$$(8) \qquad \text{Average velocity} \cong K \cdot \frac{V_{i2} + V_{i3}}{2}$$

The factor K can be a function of x (i.e., K can change with each track section that x occupies) and is determined by minimizing the least-square error in the approximation given by (8). This can be done by using an off-line simulation such as PROFILE to calculate a car's speed profile over the distance x for various values of rolling resistance, and then determining exactly the average speed over the car's run.