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Project 7663-3
December 28, 1978

Informal Note 6

AN ADVANCED RETARDER CONTROL ALGORITHM: PRELIMINARY CONCEPT DESIGN I

Background and Philosophy

Current retarder control algorithms consider only the "characteristics" of the car to be controlled in determining how to control the car. This type of control policy is simple to implement, however, it's performance is conservative since it is based on either nominal or worst-case assumptions about what the car ahead is doing.

Herein, we attempt to conceptualize a retarder algorithm which has the following attributes:

1) Considers the rolling resistance of the car ahead, as well as the car to be controlled -- We can release the second car from the retarder at higher exit velocities if the car ahead is a fast rolling car; alternatively, we must release the second car at lower exit velocities if the car ahead is a slow rolling car.

2) Considers how far ahead the first car has traveled, when the second car enters the retarder -- We can release the second car from the retarder at higher exit velocities if the first car is far ahead; alternatively, we must release the second car at lower exit velocities if the first car is not far ahead.

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3) Considers the joint distance that the first and second car travels over the same route, before one car is switched to another route -- We can release the second car from the retarder at higher exit velocities if the distance of the common route traveled is short due to either car being switched early to another route; alternatively, the second car must be released at lower velocities if the two cars must travel together over a long common route.

The algorithm conceptualized here, will not put any extra demands on measurement information; we will use the sensors which are already in place for a conventional retarder system.

However, the algorithm will require more sophisticated data-processing of sensor input to achieve improvements of importance. Since process control computers have a great deal of capability, this should offer no problems.

The algorithm described in this note presents preliminary thinking. The concepts and over-all philosophy are what is important! In all liklihood, the details will change as we do more thinking.

Information Pertinent to Control of Master Retarder

Figure 1 shows the measurement information which is available and pertinent to the control of the master retarder. (The control of the group retarder is similar and is discussed later.) In particular:

- R_i -- Rollability of car i
- L -- Length of master retarder
- V_{i1}-- Retarder entrance velocity of car i
- T_{i1}-- Time car i enters retarder
- V_{i2}-- Retarder exit velocity of car i
- T_{i2}-- Time car i exits retarder

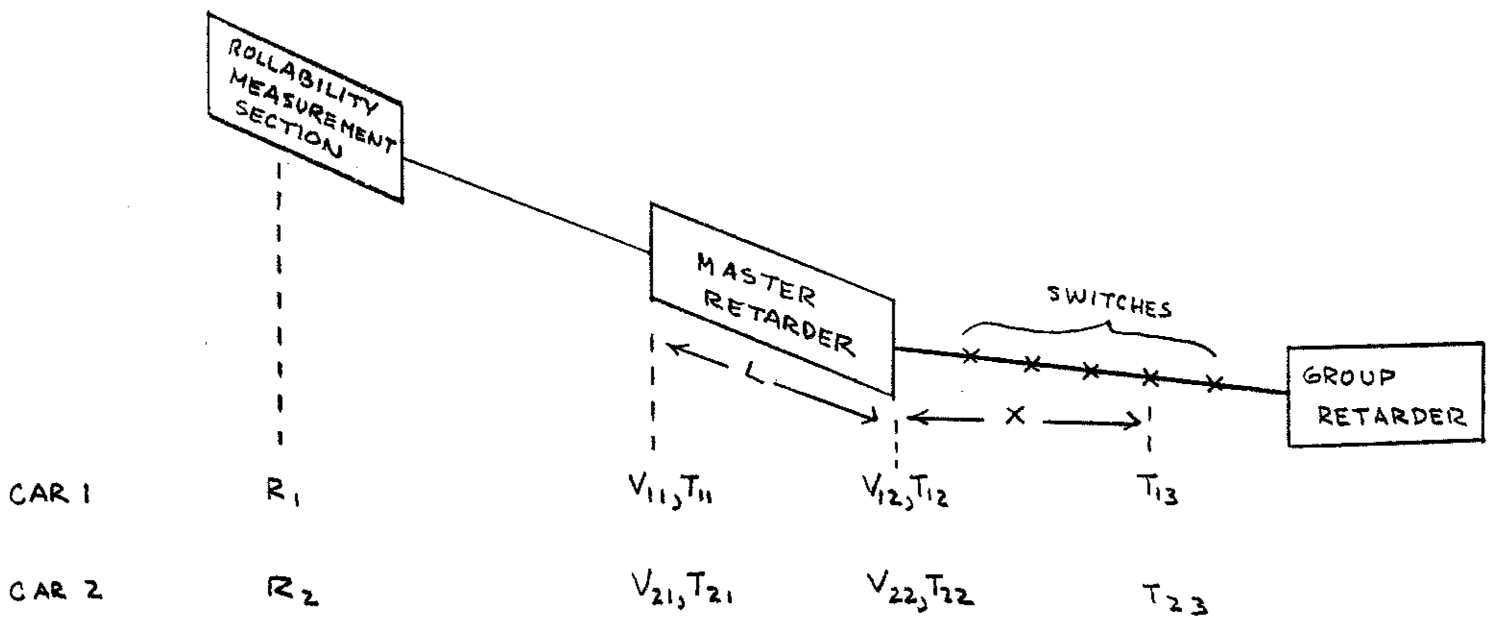

FIG. 1: INFORMATION PERTINENT TO CONTROL OF MASTER RETARDER

- X -- Joint distance of travel of cars 1 and 2 before either car is switched off common route.
- T_{i3} -- Time car i reaches distance X.

The availability of most of the above information is reasonably obvious. The parameter X is obtained by knowing the assigned class track for each car* and a "precalculated table" giving the joint distance of travel for two cars going to two specified class tracks. If the joint distance of travel is beyond the group retarder, then X is set equal to the distance to the group retarder.

The value of T_{i3} is a calculated value.

A Headway Control Philosophy

If we had perfect state information (i.e., continuous position and velocity measurements) as well as complete control (i.e., continuous ability to extract or impart energy), then the problem can be treated as a problem of controlling the headway of a string of cars (with speed constraints) using modern control theory procedures (see Ref. 1).**

However, even though we do not have perfect state information and complete control,it's appropriate to look at the problem as primarily a headway control problem with "auxillary" constraints. In particular, we want to choose the retarder exit velocity of the second car so that the headway at distance X (i.e., where switching occurs) is greater than a specified value which we shall call H^o.

*The assigned class track of each car is known to the process control computer, since the information is needed to throw the switches.

** Ref 1: W. S. Levine and M. Athans, "On the optimal Error Regulation of a String of Moving Vehicles," IEEE Transactions on Automatic Control, Vol. AC-11, pp 355-361, July 1966.

Basic Equations and Functions

The cars are governed by a second-order linear differential which is a function of the initial time, initial velocity, rolling resistance, and grades. To calculate the headway between the two cars at a distance X we are interested in calculating the time T_{13} the first car takes to travel a distance X, and where the second car is at time T_{13}. Symbollically, let us represent the calculation procedure by the following "functions".

- The time T_{13}, it takes the first car to travel X is:

$$T_{13} = F \left[R_1, V_{12}, T_{12}, X, \text{grades} \right] \quad (1)$$

- The distance X^1, the second car has traveled at time T_{13} is:

$$X^1 = G \left[R_2, V_{22}, T_{22}, T_{13}, \text{grades} \right] \quad (2)$$

Since we want the headway to be at least H^o at a distance X, then we must have $X-X^1 \geq H^o$ or from eq. (2)

$$X - G\left[\quad \right] \geq H^o \quad (3)$$

However, $G\left[\quad \right]$ is dependent on the retarder control policy on the second-car, i.e., is a function of the retarder exit velocity V_{22} and retarder exit time T_{22}. But the relationship between V_{22} and T_{22} is given by:

$$T_{22} \approx T_{11} + \frac{2.L}{V_{21} + V_{22}} \quad (4)$$

Procedure

Using the equations and functions described previously, the calculation of the exit velocity of the second-car V_{22} to give a separation of H^o at a distance X can be calculated using the following steps:

Step 1: Calculate T_{13}, the time first car travels distance X,

$$T_{13} = F\left[R_1, V_{12}, T_{12}, X, \text{grades}\right]$$

Step 2: Determine V_{22} such that the following two conditions are satisfied

$$X - G\left[R_2, V_{22}, T_{22}, T_{13}, \text{grades}\right] = H^o$$

and

$$T_{22} = T_{21} + \frac{2.L}{V_{21} + V_{22}}$$

Concluding Remarks

Concepts for a new retarder control algorithm are presented for the master retarder. The same ideas apply to the group retarder, except the exit velocity computed here is compared to the exit velocity of a distance-to-couple calculation and the minimum exit-velocity is chosen.

The key to making the algorithm practical is to find approximate and efficient ways to calculating $F\left[\ \right]$ and $G\left[\ \right]$ as given in Eqs. (1) and (2). Equations (1) and (2) are to be interpreted as "functional-mapping" in an abstract sense, since at this time we do not know whether we will integrate differential equations for the solution; make simple approximation to the grades so that we can solve algebraic equations; or pre-compute a set of solutions and store these in a table from which interpolations are performed. Whichever procedure is eventually chosen, it is to be noted that today's process control computers are extremely capable.