Geared Index Extend

Abstract

Feed applications often need to feed material at a rapid speed, slow down to a creep speed, then stop when a sensor is actuated. This type of motion profile is called "Index Extend". When an index extend is used to feed material into a press, the feed axis is usually electronically geared to follow the press speed. This Tech Note shows you how to implement a geared index extend.

Description

Figure 1 shows the desired feed profile. The application consists of a feed axis that is feeding material into a rotary press. A start input is generated when the press opens, and causes the axis to accelerate to a rapid feed. After feeding a preset length, it decelerates to a creep speed. Then, when a stop input occurs, it comes to a complete stop. The stop input is generated by a mark placed on the material. When the start input occurs again, the whole sequence is repeated.

![Figure 1, Desired Feed Profile](image)

In this example, the profile is electronically geared to a pacer encoder which means speeds are expressed in terms of a ratio of feed speed to pacer speed. Likewise, time is expressed in units of pacer travel.

The profile consists of three motion statements as shown in Figure 1. The first is a GEAR AT \( \text{speed} \) AFTER sensor statement. It accelerates the axis up to the creep speed when the start sensor is actuated. This geared motion remains active throughout the entire time the feeder is operating, the desired feed profile is obtained by superimposing two other geared motions on it.

The second is a REPEAT GEAR FOR distance IN pacer distance statement that superimposes a rapid advance on the initial creep speed as soon as the axis reaches creep speed.

The third is a REPEAT GEAR AT \( -\text{speed} \) AFTER sensor UNTIL sensor statement. The AT \( \text{speed} \) exactly cancels the creep speed so the axis stops when the stop sensor is actuated. The AFTER sensor specifies that the canceling motion will not begin until the "stop sensor" has
been received. The UNTIL sensor specifies that when the “start sensor” occurs, the canceling canceling move stops, allowing the axis to accelerate back to the creep speed. As soon as it reaches the creep speed, the second statement REPEATs and the whole process repeats continuously.

The remainder of this Tech Note deals with how to calculate the parameters for each of these gear statements.

Implementation

The actual motion statements used to create the feed profile will be:

\[
\begin{align*}
\text{GEAR feeder AT } & \text{Cspd TO 360*Pmax IN Ca AFTER start} \\
\text{REPEAT GEAR feeder FOR } & \text{Rindx IN Rp,Ra,Rc} \\
\text{REPEAT GEAR feeder AT } & \text{Cspd TO 360*Pmax IN Da,Ca UNTIL Start AFTER stop}
\end{align*}
\]

To calculate the motion parameters used in these statements you will need values for the application parameters shown in Figure 3. These are:

- **Pmax**  Max press speed (cycles per min)
- **Cspd**  Creep Speed at max press speed (thousandths of an inch per min)
- **Cdst**  Creep Distance (thousandths of an inch)
- **Dstp**  Stopping distance from creep speed after stop input (thousandths of an inches)
- **Plen**  Product length (thousandths of an inch)
- **Popen**  Press Open angle (degrees)
- **Racc**  Portion of rapid feed that consists of acceleration (percentage)
- **Rdec**  Portion of rapid feed that consists of deceleration (percentage)

The following calculations assume you have set the user units as follows:

- Press position user units = press degrees
- Press speed user units = cycles per minute
- Feeder position user units = thousandths of an inch
- Feeder pacer position user units = degrees
Inspd.Mul must be set to the number of pacer encoder counts per pacer user unit. Outspd.Mul must be set to the number of follower encoder counts per 1/1000 inch.

GEAR Parameters

Cspd and Pmax are given as part of the application data. This leaves Ca, R indx, Rp, Ra, Rc, and Da to be calculated. The MotionBASIC® code used to calculate these values is shown below, for those interested in understanding the mathematics behind the equations, refer to the "Calculations" section.

\[
\begin{align*}
S! &= \frac{\text{Cspd}}{(360 \times \text{Pmax})} \\
\text{Rpdst} &= \text{Popen} - \left(\frac{\text{Cdst}}{S!}\right) - \left(\frac{2 \times \text{Dstp}}{S!}\right) \\
A &= \frac{\text{Rpdst} \times \text{Racc}}{100} \\
C &= \frac{\text{Rpdst} \times \text{Rdec}}{100} \\
B &= \text{Rpdst} - A - C \\
\text{Rfdst} &= \text{Plen} - \text{Cdst} - \text{Dstp} \\
R! &= \frac{(2 \times \text{Rfdst} - S! \times C)}{(A + 2 \times B + C)} \\
\text{Ca} &= \frac{A \times S!}{R!} \\
\text{Ra} &= A - Ca \\
\text{Rc} &= C \\
\text{Rp} &= \text{Rpdst} - \text{Ca} \\
\text{Rindx} &= \text{Rfdst} - (\text{Rp} + \text{Ca}/2) \times S! \\
\text{Da} &= 2 \times \frac{\text{Dstp}}{S!}
\end{align*}
\]

The value used for Da must be tested to make sure they are greater than the minimums allowed for your particular axis configurations. To find out how to do this search the MotionBASIC® Hypertext manual for \textit{Pdist}.
Calculations

First we must convert the creep speed into units of thousandths of an inch per pacer degree.

\[ s = \frac{Cspd \text{ (thousandths per min)}}{360 \text{ (degrees per cycle)} \cdot Pmax \text{ (cycles per min)}} \]  

[thousandths of an inch per degree]

Next, calculate the press angle required for the rapid feed, creep, and decel portions of the motion.

\[ Pcdst = \text{Distance Pacer moves during constant speed portion of creep} \]
\[ = \frac{Cdst}{s} \text{ [degrees]} \]

\[ Pddst = \text{Distance Pacer moves during creep decel} \]
\[ = \frac{2 \cdot Dstp}{s} \text{ [degrees]} \]

\[ Rpdst = \text{Distance Pacer moves during rapid feed} \]
\[ = Popen - Pcdst - Pddst \text{ [degrees]} \]
\[ = Popen - \frac{Cdst}{s} - \frac{2 \cdot Dstp}{s} \text{ [degrees]} \]

Now we can calculate the acceleration, cruise and deceleration durations in terms of pacer distances.
Next we need to calculate peak speed achieved during the rapid feed.

\[
R_{fdst} = \frac{Plen - Cdst - Dstp \text{ [inches/1000]}}{\left(\frac{a}{2} + r \cdot b + \frac{(r - s \cdot c)}{2} + s \cdot c\right) \text{ [inches/1000]}}
\]

\[
r = \frac{R_{fdst} - \frac{s \cdot c}{2}}{\frac{a}{2} + b + \frac{c}{2}} = \frac{2 \cdot R_{fdst} - s \cdot c}{a + 2 \cdot b + c} \text{ [thousandths of an inch per degree]}
\]

Also, calculate the index distance and pacer distances used in the rapid feed GEAR statement.

\[
Ca = \frac{a \cdot s}{r} \text{ [degrees]}
\]

\[
Ra = a - Ca \text{ [degrees]}
\]

\[
Rc = c \text{ [degrees]}
\]

\[
R_{index} = R_{fdst} - (Rp + \frac{Ca}{2} \cdot s) \text{ [inches/1000]}
\]

\[
Rp = Rpdst - Ca \text{ [degrees]}
\]

Finally, we calculate the decel pacer distance used in the dwell GEAR statement.

\[
Da = Pddst - \frac{2 \cdot Dst \cdot s}{s} \text{ [degrees]}
\]