Cheat Sheet

Contacts regarding Code Development

Paul Haworth (Implemented servo code on H16S)

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Main equations

Steady state dancer displacement OH20S

is the steady state displacement (inches)

is the set point (inches)

is the payout velocity in (inches per minute)

is the servo loop effective gain in (rad/s)

Nominal constant ranges for OH20S

Note that these are **not** strict requirements, just ranges that have been used previously. After every set of parameters, it is important to verify the margin for error from each end stop is at least 0.25’’. Usually this number is around 0.5’’.

Steady state dancer displacement H16S

The difference between the OH20S and the H16S is that a threshold value exists after which the gain is increased. The reason this control change is implemented is due to the top speed and the cut speed being significantly different. Although there is also code for the OH20S to use the same control scheme, currently in production it has been disabled.

is the steady state displacement (inches)

is the set point (inches)

is the payout velocity in (inches per minute)

is the servo loop effective gain in (rad/s)

is the dancer threshold after which the gain is doubled (inches)

Nominal constants and ranges for H16S

Controller structure

The controller converts dancer error into a tow surface speed command. Surface speed is used to model performance despite rotational speed commands being sent. The reason for this is that the same dancer dynamics are to be maintained during any state of the spool diameter. A division to convert surface speed to the correct rotational speed is calculated afterward.

The controller is modelled as a first order system in Laplace domain

Converting to a discrete implementation with being the sample time can be done via Euler approximation.

Dancer plant model

Key lessons from H16S development:

1. Since velocity commands are sent from the motor, inertia ratios can be very large with adequate tension control performance (H16S regularly operates with a ratio higher than 50:1)
2. Controllers that tend to reduce the steady state dancer error should not be used. The reason is that the dancer must displace more at higher speeds to give reasonable stopping distance so that motors will not over torque.
3. If the bandwidth of the velocity control loop is around 10Hz, removing the dynamics of velocity transfer functions is a reasonable assumption
4. Generally, the add and cut events create the largest torque requirements from the motor if the acceleration phase is 0.5G
5. The gearbox must have a static moment rating to spool inertia in a cantilevered fashion
6. Peak voltages must be controlled to mitigate the possibility of damaging the motors. Currently TVS diodes are used to absorb regen onto the bus.
7. Backer winding issues, tend to happen on add/cut
8. From experimental extrapolation and simulation it is possible to reach top speeds of 5500ipm if add/cut speeds are unchanged from 2000ipm and the control loop is pushed to it’s limit. This would require a reduction ratio of 8:1 on the SM23165MT instead of 10:1
9. Using the dancer data over time, the time of a cut event can be estimated and tow end placement as a result can also be estimated (RIPIT)
10. Moog Animatics SmartMotors are very easy to code and set up relatively speaking compared to most other servo systems. They are very valuable for temporary experimental setups.

Key lessons from OH20S development:

1. Backer winding issues are caused by general payout, not as much by add/cut events
2. The kinetic energy within a spool is greatest during payout near 14’’ diameter since the cassete makes up a large portion of the rotating inertia
3. Modbus is the current communication method between the PLC and the PMAS (motion controller). This was very difficult to get working since communications/handshakes must be implemented on the PMAS side, and interpretted 1:1 on the PLC side correctly.
4. Due to space constraints, the only motor drive pair that was found to be viable in terms of form factor and power density were the FLA-20 motors by Harmonic Drive and the Gold DC Whistle by Elmo Motion. It is possible that future developments will yield better options.
5. Related to point 3, an attempt to use an AnyBus converter on the EtherCAT chain was done and it was a failure. The PMAS could not recognize the device. There might be another way, but currently it is unknown whether the PMAS supports any bus converter device.
6. Controllers that tend to reduce the steady state dancer error should not be used. The reason is that the dancer must displace more at higher speeds to give reasonable stopping distance so that motors will not over torque.
7. If the bandwidth of the velocity control loop is around 10Hz, removing the dynamics of velocity transfer functions is a reasonable assumption
8. The gearbox does not need a large static moment rating as the spool has a center of mass centered on the motor/gearbox combo
9. Generally, the add and cut events create the largest torque requirements from the motor if the acceleration phase is 0.5G
10. Peak voltages must be controlled to mitigate the possibility of triggering a reset on the power supplies. Currently TVS diodes are used to absorb regen onto the bus.
11. Momentary overcurrent issues cause failures on the OH20 specifically Head 6. There should be a way to recover from this state via software.
12. Although cut speed was reduced in production, the servo creel has the capability of cutting at 4000ipm which was tested in house. 5000ipm was tested, and might be possible if dancer stroke and cutter design were optimized.

H16 Motor Settings

Below is the code that specifies the tuning constants for the SM23165MT. These were tested to be working on the H16S Gen 1 although it is possible changes were made in production machines.

Notes:

* 10:1 reducer, system should be retuned if the reduction is changed
* Since dancer tow tension acts as a disturbance torque, integral gain should be limited to prevent steady state oscillation

Clicking the code will open a document and code can be copied



SM23165MT with 10:1 TP004 (H16S First generation servo creel):

Maximum speed is 4000rpm at the input of the 10:1 reducer

Add speed was originally specified for 2000ipm cut speed, 3000ipm was tested and was verified to be possible. However, this created other reliability issues.