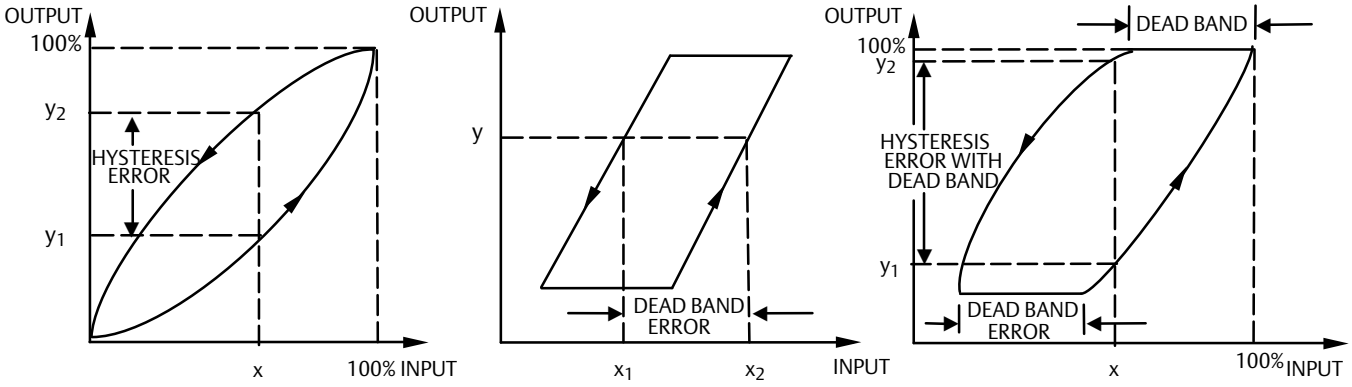
Dead Band Plus Hysteresis Estimation with ValveLink™ Diagnostics

Background

Dead band and hysteresis are important nonlinearities that can adversely affect process control. Figure 1 shows input and output graphs for hysteresis, dead band, and dead band plus hysteresis. Hysteresis is a path dependent characteristic that can be attributed to materials not being able to return to their original shape and size after being stretched or deformed. Dead band represents the amount of signal change required to reverse direction and is characterized by a zero slope region where the input signal reverses. Dead band can usually be attributed to valve friction (packing, actuator seal rings, and valve seal rings) and pneumatic dead zones in the instrumentation.

Figure 1. Hysteresis, Dead Band, and Dead Band plus Hysteresis Curves



For control valves, dead band is the dominant nonlinearity whereas hysteresis is a secondary effect. Hysteresis can be estimated by subtracting dead band from the dead band plus hysteresis data. However, since hysteresis is generally negligable and difficult to discern from experimental error, dead band and hysteresis are not separated and test results are reported as the sum of these nonlinearities.

Allowable dead band plus hysteresis is process dependent but is typically specified to be ≤ 1% for the entire valve assembly, which comprises the valve, actuator, and positioner.

Dead Band plus Hysteresis Test Definition

Dead band plus hysteresis can be estimated at the factory using a Series 3 Factory ValveLink test. Although dead band plus hysteresis is a factory test, results can be imported and viewed in all versions of ValveLink software. Dead band plus hysteresis tests can be run at nominal travels of 5%, 25%, 50%, 75%, and 95%. If a test point is not specified, dead band plus hysteresis will be evaluated at a nominal travel of 50%.

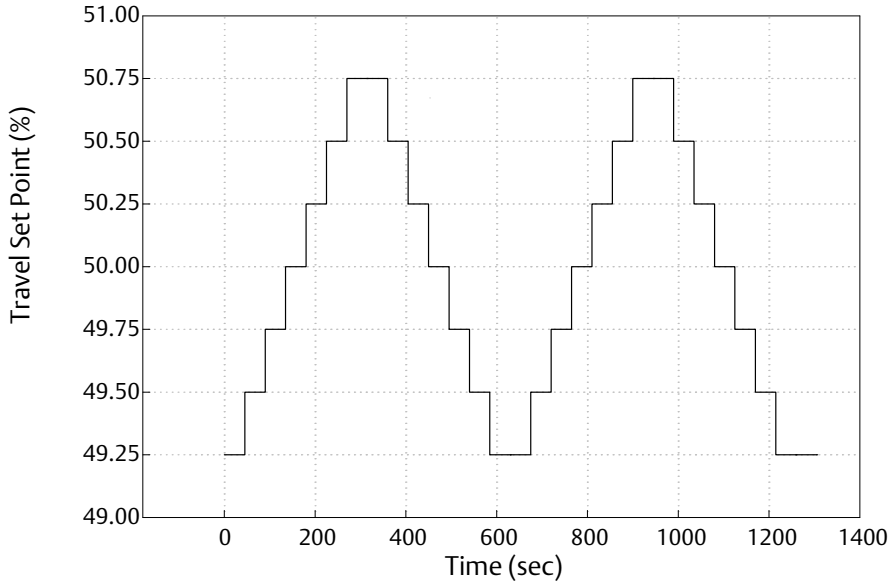
Test Procedures

Dead band plus hysteresis is a static measurement that can be estimated using a quasi steady-state test signal. All tests are performed using standard digital valve controller diagnostic procedures with the cutoffs and characterization disabled and with the travel integrator disabled. This is done to prevent limit cycles, overshoots, or other transients that would invalidate the dead band plus hysteresis estimate.

The dead band plus hysteresis test is a 29 point step test that consists of series of 0.25% steps that slowly move the valve in the opening and closing directions. Figure 2 shows a test signal centered around 50%. Test signal span is 1.5% and each step is held for 45 seconds, although this can be set to 60 or 90 seconds in the factory to ensure that quasi steady-state conditions are met.

The dead band plus hysteresis test consists of two sequences. The first sequence is a break-in cycle that moves the valve through its dead band and establishes a valid starting point for the second sequence. Data from the break-in cycle are not analyzed. The second sequence is the test cycle and data from this sequence are used to estimate dead band plus hysteresis.

Figure 2. Dead Band plus Hysteresis Test about a Nominal Set Point of 50%



Test Results

Four graphs are used to display test results: step response time series, step response with supply pressure, step response with drive, and dead band plus hysteresis X-Y plot.

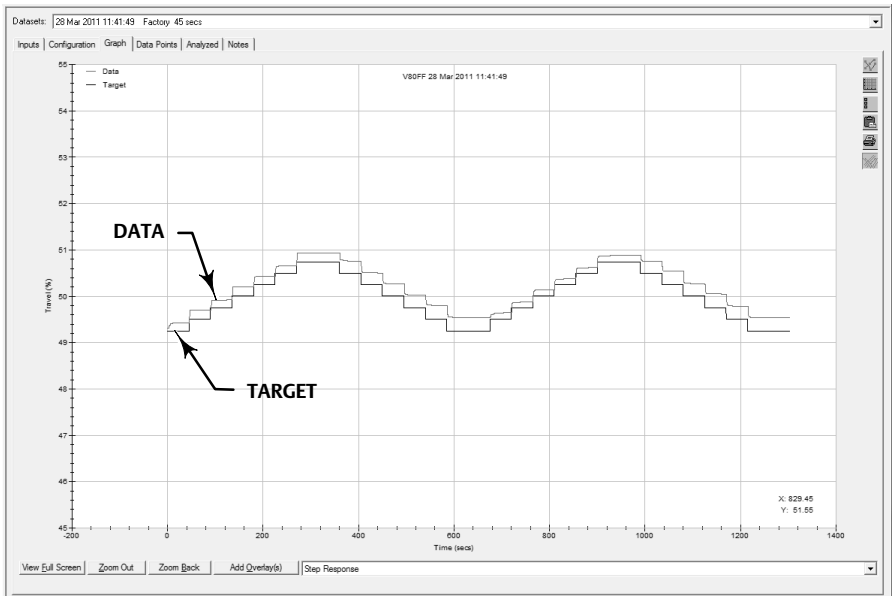
The step response graph displays travel set point and travel time series data. A typical time series plot of travel set point and travel is presented in figure 3. This graph is used to make sure that steady-state conditions have been reached before the next step is implemented. If this is not the case, the dead band plus hysteresis test can be rerun with a longer step hold time. This graph can also be used to roughly estimate dead band by counting the number of 0.25% steps required to reverse direction.

Step response time series data with supply pressure and drive signal are also available and are recorded for completeness.

Finally, steady-state data can be displayed on an X-Y plot where set point is plotted on the x-axis (input signal) and travel is plotted on the y-axis (output signal). A sample X-Y dead band plus hysteresis is shown in figure 4.

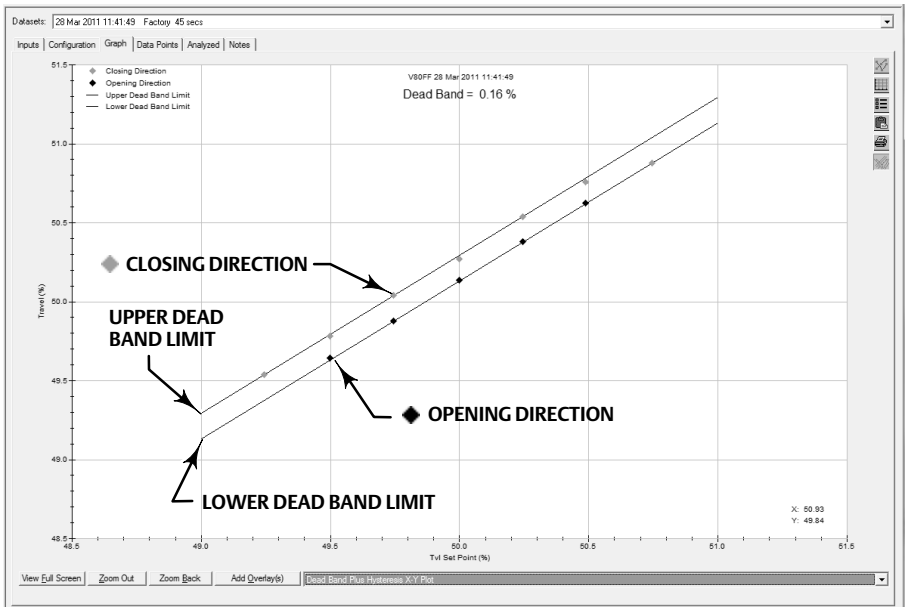
The ideal response of a control valve is a straight line with unity slope. Dead band plus hysteresis can be estimated by drawing lines parallel to the ideal response that band the data. The width between the bands provides the best estimate of dead band plus hysteresis.

Figure 3. Typical Travel Set Point and Travel Time Series Plots



Note: The first cycle is a break-in cycle. The second is a test cycle.

Figure 4. Dead Band plus Hysteresis X-Y Plot with Unity Slope Bands



Data Export

Dead band plus hysteresis data from factory ValveLink can be exported as a standard step study test. When imported into ValveLink 11.5 or higher, time series and dead band plus hysteresis X-Y plots can be displayed. For earlier versions of ValveLink, only time series data will be displayed.

References

[1] ANSI/ISA-75.05.01-2000 (R2005), “Control Valve Terminology.”

[2] ANSI/ISA-75.13.01-1996 (2007), “Method of Evaluating the Performance of Positioners with Analog Input Signals and Pneumatic Output.”

[3] ANSI/ISA-75.25.01-2000, “Test Procedures for Control Valve Response Measurement from Step Inputs.”

[4] ANSI/ISA-TR75.25.02-2002, “Control Valve Response Measurements from Step Inputs.”

[5] IEC 60534-1, “Industrial-process control valves - Part 1: Control valve terminology and general considerations.”

[6] IEC 60534-4, “Industrial-process control valves - Part 4: Inspection and routine testing.”

[7] “Control Valve Dynamic Specification,” Version 3.0, EnTech, 1998.

[8] ANSI/ISA-51.1-1979 (R1993), “Process Instrumentation Terminology.”

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