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Partial Stroking on fast acting applications

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Partial stroking: This is a widely used method to avoid sticking of a ball valve when it is not operated for some time. It is also used to reduce the actuator size and thus the total cost of the valve + actuator. Usually an equation similar to the following is used to size actuators for ball valves:

$T_{act} = T_{valve} \times C_{medium} \times C_{temp} \times C_{freq}.\times C_{crit}. \times C_{cont}$

Where:

T_{act}	=	Actuator Torque to be considered for actuator selection
T_{valve}	=	Torque required to operate the valve under full dP conditions
C_{xxx}	=	Multiplying factors depending of xxx

In case the valve is regularly moved the required torque of the actuator is reduced. Therefore partial stroking influences the performance of the valve / actuator assembly.

Partial stroking should not be confused with Partial Stroke Testing or even Partial Stroke Monitoring.

Partial Stroke Testing or Monitoring is performed by specifically developed devices that move the valve over part of the stroke and gain data during the valve movement regarding the status of the valve / actuator combination.

The necessity for partial stroking is now used as a possibility to gather data. These data should then show the status of the valve / actuator combination.

The terms testing and monitoring in this respect are often mixed. Monitoring is what the IEC describes as diagnostics, an automated action that virtually continuous verifies the status of the equipment.
In the electronics this is possible and several examples can be found. We can for instance continuously measure the value of a resistance to verify it. However we cannot continuously measure for instance internal friction on final elements.
The term testing is not correct either. A test should not influence the result, for instance a thermometer should not heat the fluid.

It is preferred to use simply the term partial stroking.

This brings us to the terms diagnostics, the IEC 61508 and 61511 do not define diagnostic testing but only give a definition for the term diagnostic coverage.
Diagnostic coverage is the ratio of the (dangerous) detected failures to the total failures as detected by automatic diagnostic tests. The IEC 61511 adds that faults detected by proof tests are excluded.

A prooftest is a periodic test of the safety instrumented system, the IEC 61508 adds that the target should be to detect 100% of all dangerous failures and all safety functions should be checked.

Based on this we feel that partial stroking should not be considered a proof test. Partial stroking is born out of and focused on the breakaway torque of a ball valve. Partial stroking does not verify if the final element performs its safety function that is of course closing within a certain time.

Therefore partial stroking should be considered on its best a diagnostic test. In some respect this could be contradicted while most partial stroke devices do not perform the test automated and do not shut-down the safety system when a fault is detected. We will however consider it a diagnostic test.

Please note in this discussion we concentrate on the valve / actuator combination and not on the solenoids used to operate the final element. Based on the performance data of solenoids, even supported with TUV certification, and the fact that they are usually redundant per final element their contribution to the total PFD is reduced and therefore do not require a shorter prooftest interval then the valve / actuator combination. Although some partial stroking devices operate the solenoids and consider this a prooftest of the solenoid we do not include this in the present discussion.

In order to define the advantage in the total PFD of the final element we assume that the following (simplified, but often used) equation is correct:

$$PFD_{AV} = DC_{PT} \times \tfrac{1}{2} \times \lambda_D \times T_{PT} + (1-DC_{PT}) \times \tfrac{1}{2} \times \lambda_D \times T_{FT}$$

Where

λ_D	=	Dangerous failure rate [1/t]
T_{PT}	=	Partial stroke test interval [t]
T_{FT}	=	Full stroke test interval [t]
DC_{PT}	=	Diagnostic Coverage of partial stroke test (%)

The dangerous failure rate is of course the failure rate of the final element based on a long period of not moving, this is the failure rate without interference of the test on the valve / actuator combination. In case a reduced failure rate is used based on improved performance due to the partial stroking we should not take credit for the partial stroking in the PFD a second time.
So before calculating the PFD the underlying data should be verified. It should be derived from the third party report if the mentioned failure rate is applicable with or without regular partial movement. If the failure rate is already applicable for regular partial movement PFD_{AV} is defined as:

$$PFD_{avps} = PFD_{AV} = \tfrac{1}{2} \times \lambda_{DPS} \times T_{FT}$$

Where:

PFD_{avps}	=	PFD based on regular movement by partial stroking
λ_{DPS}	=	Dangerous failure rate based on regular movement (1/t)

Actually in case the failure rate and the actuator torque are based upon the assumption that the valve will be stroked every couple of weeks or months the safety loop should be re-evaluated. In this case the partial stroking has become a safety related device, if no partial stroke is performed the final element may not operate on demand.

We will therefore assume here that the failure rate and actuator sizing is always based on a population without partial stroking.

In that case the (simplified) formula shown before applies. We should now define the diagnostic coverage in order to calculate the (approximate) advantage on the PFD_{AV} and define how often we want to perform the partial stroke test.

The diagnostic coverage is the ratio of failures detected by the diagnostics to the total dangerous failure rate.
This basically means: how many % of the dangerous failures can be detected by these diagnostic tests?

This then depends on the application.
In case we consider a general type ESD valve in a process facility the dangerous failures are probably different than in a fast acting HIPPS application where the over-pressure of a vessel is protected.
In both cases the safety mission is closure. However in most cases the ESD valve does not have severe requirements on stroking time, the valve may close in 1 seconds per inch size so for a 24 inch 48 seconds. Whereas the HIPPS valve shall avoid over-pressure by fast closure meaning 2 seconds for a 24 inch final element.
Therefore a difference should be made dependent of the application and the type of equipment. We will assume here that it concerns a HIPPS type application. A flow comes into a separator and blockage of the outlet of the separator occurs. The HIPPS valve shall close within 2 seconds to avoid over-pressure of the vessel.

In this case of course an important dangerous failure could be the stroking time. The response time should therefore be measured during a proof test. Normally the “sequence of event recorder” in the safety system will measure the times and record the test.
During partial stroking the full stroke stroking time is of course not measured.

For some valve designs the “break-away” torque may increase in time and even exceed the re-seating torque. The fact that the valve still departs from the open position can be verified. Some smart devices are even able to indicate required torque or an increase in required torque. Although variations due to the process conditions like pressure and temperature are not taken in account in these devices.

The partial stroking devices do not verify if the valve actually closes. The device closes the valve only 10-20% and then re-opens it. In a simple way the question should be: Can we estimate how many percent of the failures occur in this first 10-20% stroke? Actually it would be fair to say that the majority of the failures occur at closure or close to closure. When the ball is moving at its highest speed.
Of course here again we see the difference between standard applications and fast acting applications.

Therefore on fast acting applications the Diagnostics Coverage factor cannot be over 30-40% even though the IEC 61508 or 61511 indicates that a low coverage is in the 60% region. The annex C indicates that the DC should always come from the Failure Mode and Effect Analysis and not from the sample tables in the IEC itself. Only the FMEA of the product for the application can define the Diagnostic Coverage Factor.

Generally speaking most operators reduce the amount of data that should be saved for future use. And thus we want to reduce the number of partial strokes we perform, while the results of each test shall be recorded and saved in SIL3 or SIL4 applications. We can therefore state safely that basically the minimum partial stroking interval can be considered to be 2-3 months or maximum 6 times a year.

In case we select proper equipment the proof test interval is one year.
Now based on the above we can indicate the advantage of partial stroking:

$PFD_{AV} = DC_{PT} \times ½ \times \lambda_D \times T_{PT} + (1-DC_{PT}) \times ½ \times \lambda_D \times T_{FT}$

Where:
$T_{PT} = {}^1/_6 \times T_{FT}$

$PFD_{AV} = ½ \lambda_D \times T_{FT} \times ({}^1/_6 \times DC_{PT} + (1-DC_{PT}))$

$PFD_{AV} = ½ \lambda_D \times T_{FT} \times (1-{}^5/_6 \times DC_{PT})$

If DC_{PT} = 40% then: $PFD_{AV} = ½ \lambda_D \times T_{FT} \times 0{,}667$

If DC_{PT} = 60% then: $PFD_{AV} = ½ \lambda_D \times T_{FT} \times 0{,}5$

Normally a reduction of 50% to 65% only for the final element will not result in an increase in SIL for the complete loop.

This is of course taking in account that the partial stroking device is capable of recording data on fast acting applications. Based on a full stroke time of 2 seconds and a partial stroke of 10% the device has approximately 0,2 to 0,3 seconds to start closure, stop closure, re-open and record the data.

So concluding the above:

- Too often partial stroking will result in a vast data flow, which is to be stored and evaluated.
- On higher SIL and fast acting applications it cannot replace a real proof test.
- The diagnostic coverage shall be defined per application, per valve / actuator type.
- On fast acting and severe applications the diagnostic coverage is lower than 60%.
- Both initial and operational costs increase where the improvement in PFD or SIL level is reduced on fast acting applications.
- Dependent of the required response time it shall be examined if the partial stroke device is capable of acting fast enough.
- The partial stroke device should be able to perform a shut-down in case the data show that the final element is no longer safe.
- Partial stroking devices will increase the spurious trip rate of the safety loop and thus reduce the production availability of the plant.

So the conclusion is that for fast acting final elements used as last level of defense in higher SIL applications it is preferred to select equipment with a sufficiently low failure rate to allow for a yearly proof test. Selecting more reliable equipment is preferred over selecting partial testing.