Associazione Italiana Strumentisti

ISA Italy Section

Associazione Termotecnica Italiana
Sezione Lombardia

# VALVOLE DI CONTROLLO E INTERCETTAZIONE, SISTEMI DI AZIONAMENTO, DISCHI DI ROTTURA E DISPOSITIVI DI SICUREZZA UTILIZZATI NELL'INDUSTRIA DI PROCESSO

**Milano, 18 Aprile 2018**
**Auditorio TECNIMONT**

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# Flow Coefficient validation through Computational Fluid Dynamics (CFD) of Control Ball Valves for Oil&Gas applications

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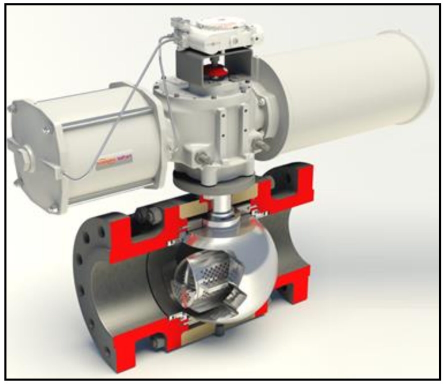
Experience In Motion

# Numbers matter

- Correct *sizing & selection* of a control valve is a *key activity*, that relies on an *extensive database* of values, coefficients and parameters.

Instrument datasheet

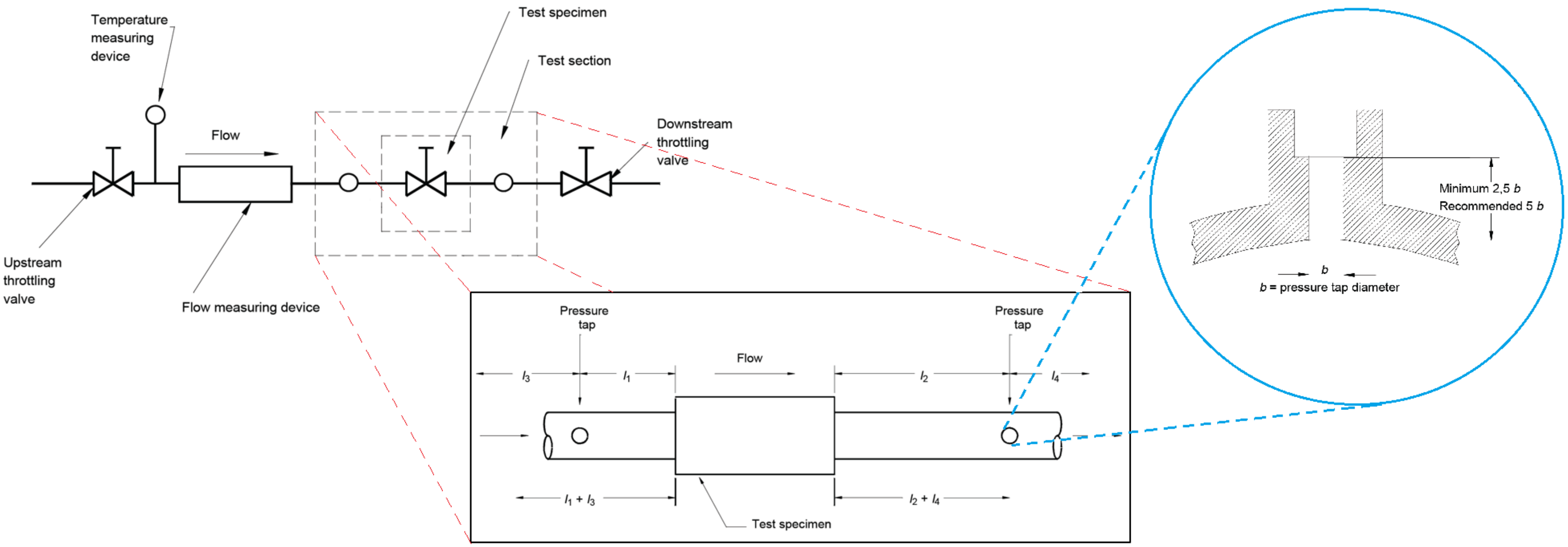


Control valve

***How & where*** **to get all those numbers for an entire product range?**

# Experimental testing

- Standards IEC 60534-2-3 or ISA 75.02, define testing procedures, test rig arrangement, measurements to determine the main variables of interest ($C_V$, $F_L$, $X_T$, etc..)



# Experimental testing

Experimental testing is *fundamental*, but has practical limitations:

- Test rig capacity & availability
- Investment in prototypes

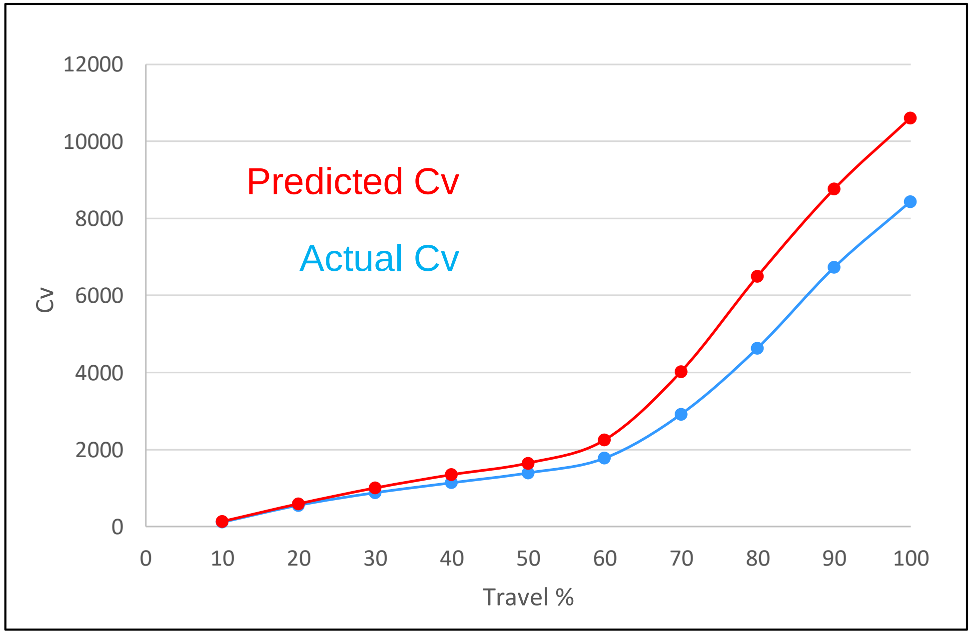
*Usually, few prototypes of small size can be tested*

***What about the untested valves?***

# Extending the experimental results

- Not all the dimensions/components scale accordingly with the valve size
- Fluid dynamics do not simply scale with the size
- Extrapolation of results from few concentrated points is not recommendable

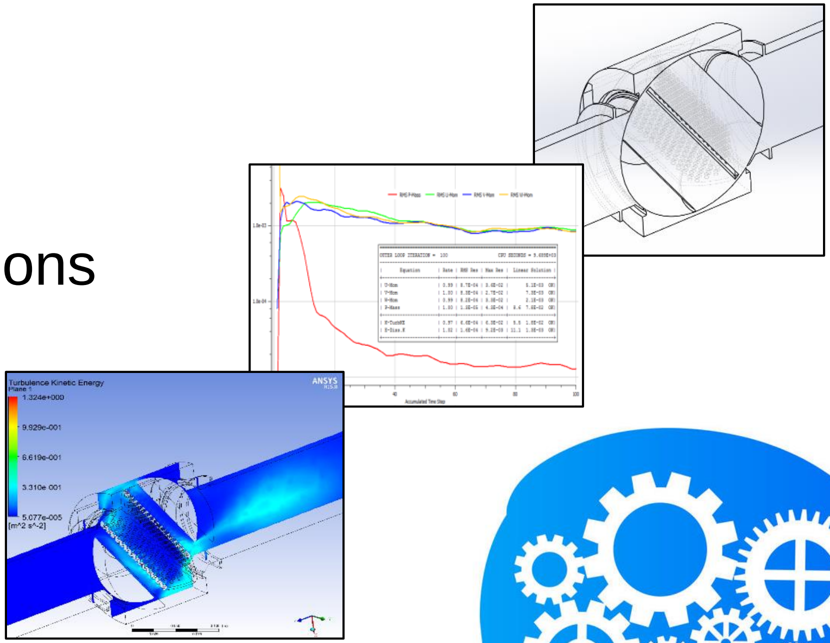
*Simple scaling of the results is not accurate enough, especially when considering more "complicated" geometries.*



# Computational Fluid Dynamics

## + Pros

- Virtual, no real physical prototypes
- Can simulate different conditions
- Cost & time saving

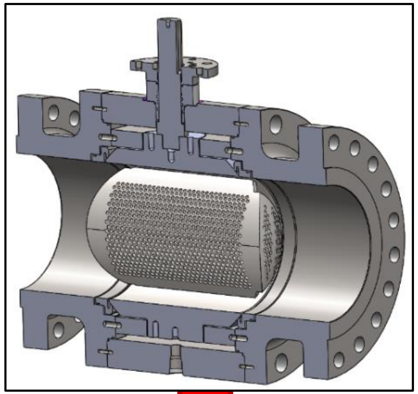



## - Cons

- …Still need some money investment
- Need to be used with adequate knowledge

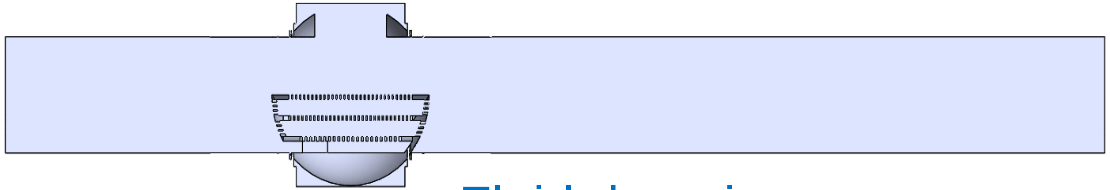
# CFD as reliable tool

Full valve
3D model

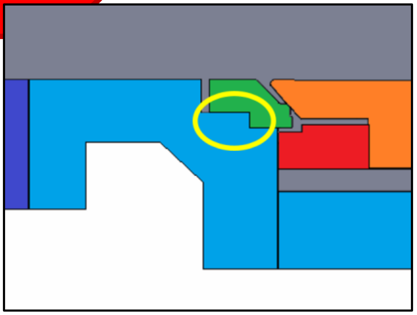


*3D Model*

- Must be accurate…
- …but not over-detailed
- Must take advantage of symmetries



Fluid domain

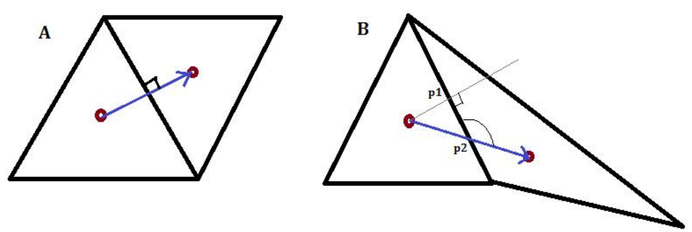


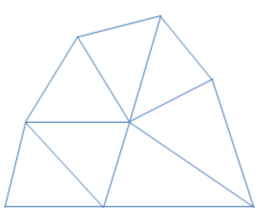
*Save computational resources & time without sacrificing accuracy!*

# CFD as reliable tool

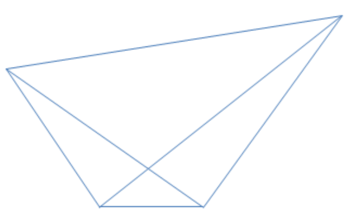
*Mesh*

- Size
- Quality of the mesh (Skewness, Smoothness, Aspect Ratio)
- Sensitiveness of the solution to the mesh

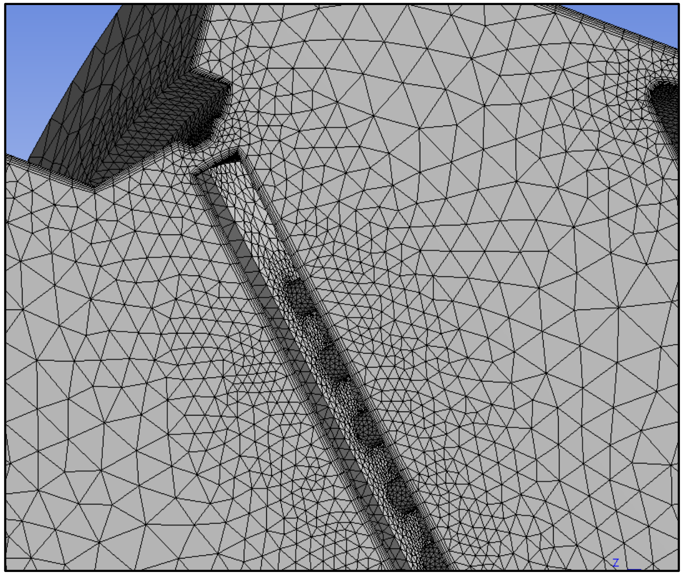


Smooth Change in cell size



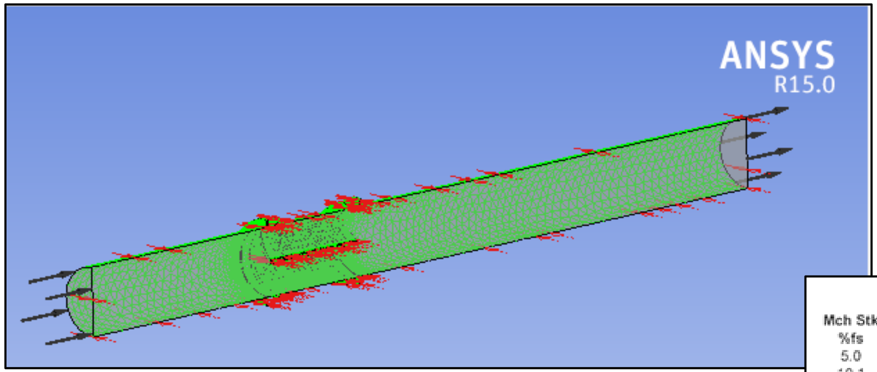
Large jump in cell size



# CFD as reliable tool

*Models & Boundary conditions*

- …must be set correctly (type, location, etc..)
- Identify a proper set of boundary conditions to verify and fine-tune the CFD methodology




Boundary setup

Experimental test conditions

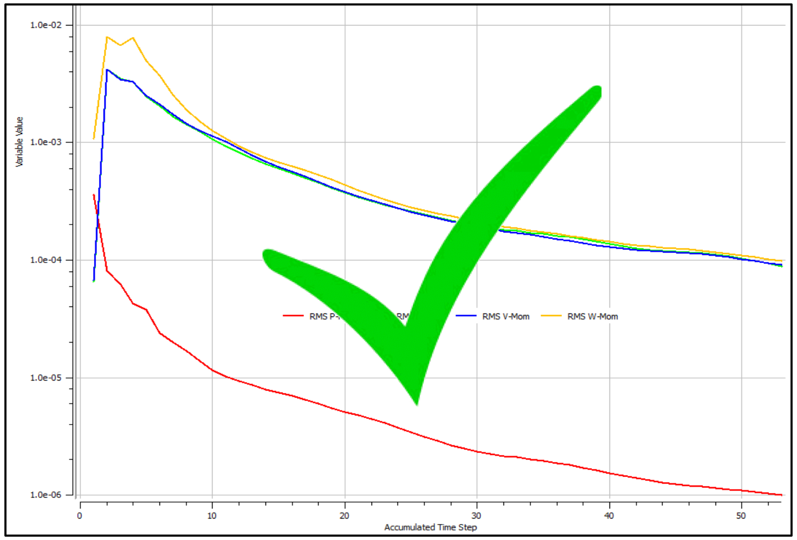
| Mch Stk | High Delta Pressure | | | | Mid Delta Pressure | | | | Low Delta Pressure | | | | Cv Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | DP | Qavg | Cv | P1 | DP | Qavg | Cv | P1 | DP | Qavg | Cv | |
| %fs | psia | psi | gpm | | psia | psi | gpm | | psia | psi | gpm | | |
| 5.0 | 101.52 | 89.23 | 0.02 | 0.00 | 102.55 | 90.27 | 0.02 | 0.00 | 102.26 | 89.98 | 0.05 | 0.01 | 0.00 |
| 10.1 | 102.39 | 90.11 | 0.02 | 0.00 | 102.19 | 89.90 | 0.02 | 0.00 | 102.14 | 89.87 | 0.02 | 0.00 | 0.00 |
| 20.1 | 101.02 | 59.53 | 21.96 | 2.85 | 102.44 | 29.61 | 15.24 | 2.80 | 102.11 | 15.90 | 10.99 | 2.76 | 2.80 |
| 30.0 | 89.45 | 60.10 | 124.88 | 16.11 | 96.22 | 30.60 | 88.69 | 16.04 | 101.13 | 6.02 | 39.29 | 16.02 | 16.06 |
| 40.0 | 64.83 | 30.49 | 218.17 | 39.53 | 82.97 | 15.51 | 155.10 | 39.40 | 98.97 | 3.17 | 70.12 | 39.41 | 39.45 |
| 50.1 | 99.13 | 59.33 | 514.98 | 66.88 | 103.42 | 29.58 | 365.28 | 67.19 | 105.13 | 6.28 | 167.85 | 66.98 | 67.02 |
| 60.2 | 96.60 | 60.78 | 787.61 | 101.06 | 103.15 | 30.27 | 559.44 | 101.71 | 108.01 | 6.44 | 258.04 | 101.70 | 101.49 |
| 70.1 | 90.76 | 50.53 | 1123.89 | 158.17 | 102.29 | 25.17 | 792.38 | 157.99 | 111.00 | 5.04 | 349.81 | 155.86 | 157.34 |
| 80.1 | 71.02 | 44.79 | 1668.99 | 249.46 | 96.39 | 22.22 | 1193.79 | 253.33 | 109.95 | 4.50 | 536.82 | 253.16 | 251.98 |
| 90.0 | 57.56 | 24.96 | 2063.65 | 413.18 | 88.77 | 12.47 | 1478.15 | 418.71 | 107.80 | 3.11 | 739.25 | 419.17 | 417.02 |
| 100.1 | 33.52 | 15.11 | 2514.30 | 647.05 | 73.11 | 7.90 | 1889.98 | 672.65 | 104.78 | 2.14 | 980.85 | 670.09 | 663.26 |

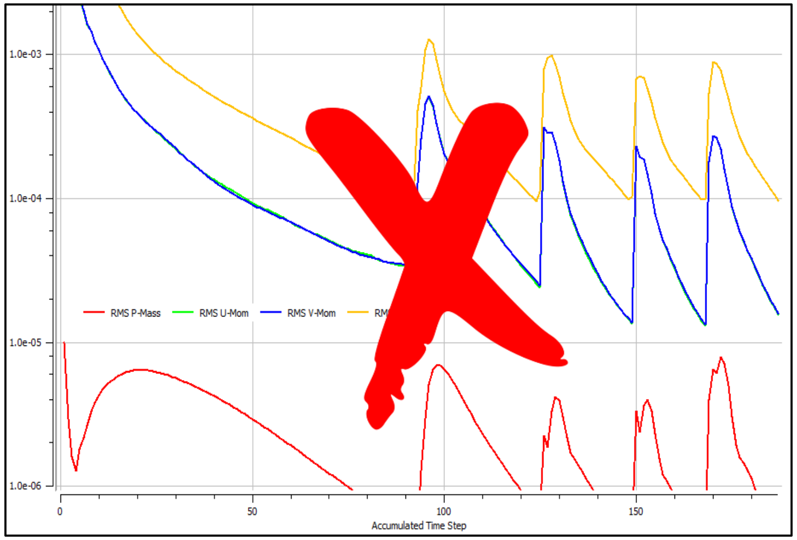
Full Stroke (in. / Deg.) : 91.88 Fluid Temp. : 49.6 +/- 0.8 °F
Barometric Pressure : 12.5 psi Minimum Reynolds Number : 40736

# CFD as reliable tool

*Check solution quality*

- Convergence & Stability
- Residuals
- Monitor of other variables of interest

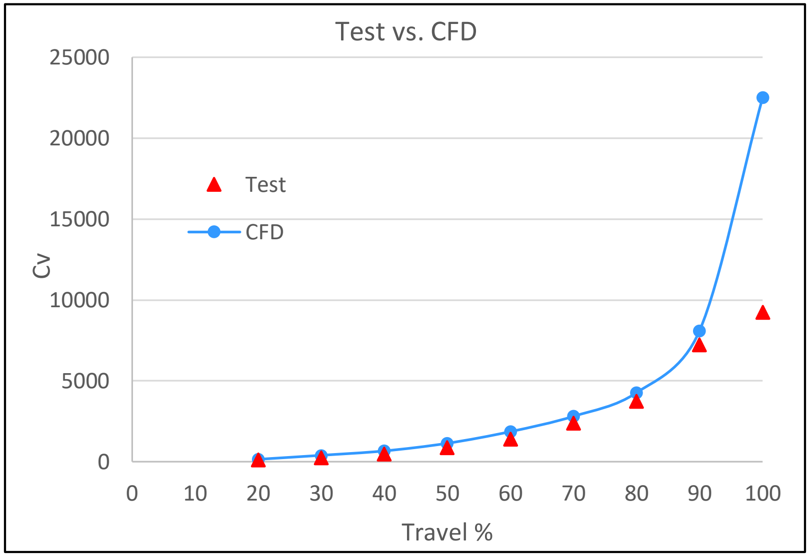


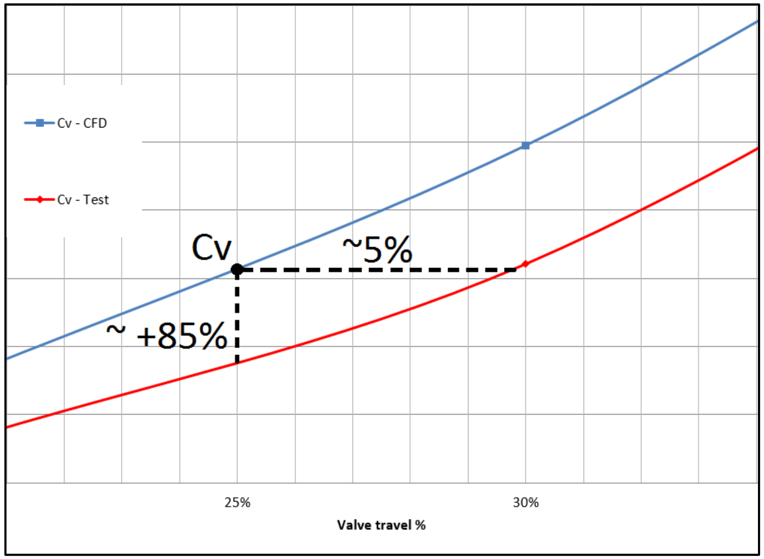



# CFD fine-tuning & validation

*CFD (first runs) vs. Experimental testing – Comparison*

- *Notable differences* observed:
  1. $C_V$ values at full opening (for some trim solution)
  2. $C_V$ values at minimum openings



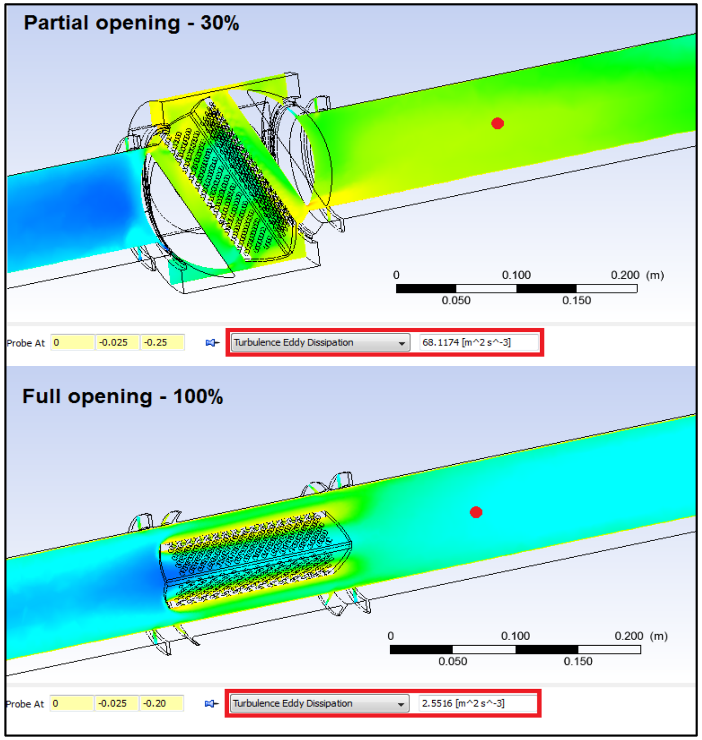



# CFD fine-tuning & validation

## *1. $C_V$ values at valve full opening*

Valve geometry changes with the opening

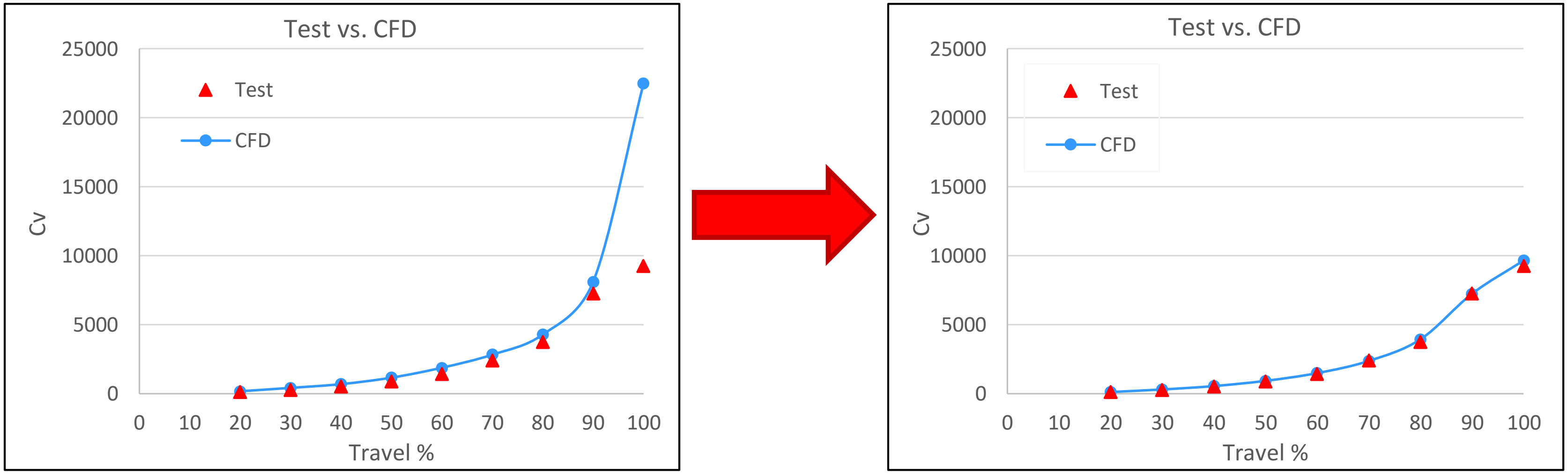
Different dissipation effect/mechanism may become relevant at different opening



# CFD fine-tuning & validation

## *1. $C_V$ values at valve full opening*

- Introduction of pipe wall roughness into the simulation



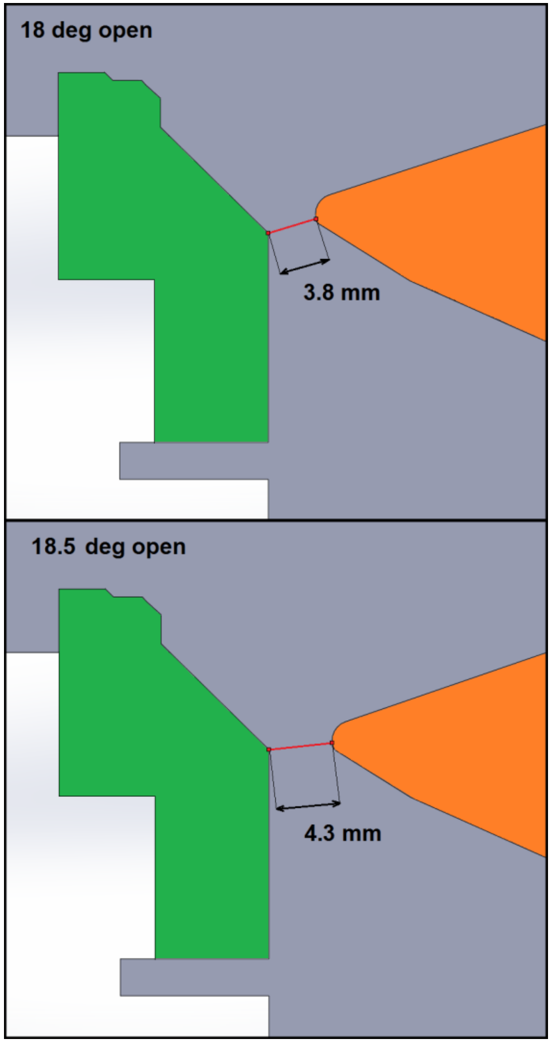

*Significant* increase of the CFD accuracy at *full open condition*

# CFD fine-tuning & validation

*2. $C_V$ values at valve minimum openings*

*While at small openings*, small differences in the ball rotation can cause relevant differences in the areas

Precise positioning of the ball during the test is important at low openings to get the correct $C_V$

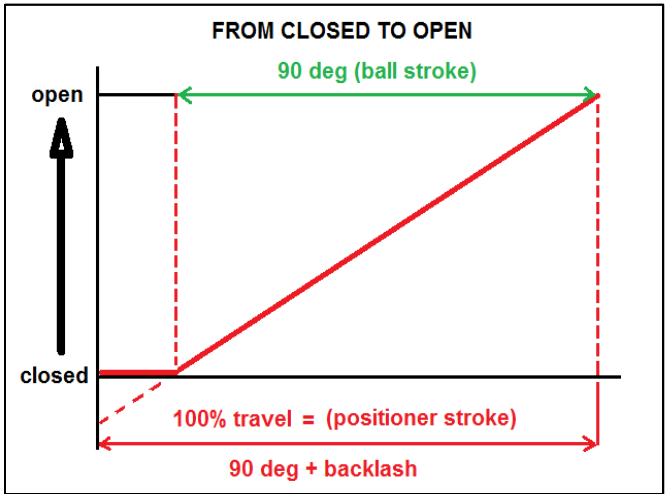


# CFD fine-tuning & validation

*2. $C_V$ values at valve minimum openings*

Measures of tested valve backlash where used to correct the CFD model openings through a simple model

Increased $C_V$ accuracy vs. test at lower openings, with minimal to no effect for mid-large openings




| Stroke % | CFD Cv | Test Cv | Diff % |
|---|---|---|---|
| 20% (*) | 42.62 | 46.11 | -7.57% |
| 30% (*) | 121.52 | 128.20 | -5.21% |
| 40% (*) | 201.71 | 205.40 | -1.80% |
| 50% (*) | 291.99 | 305.45 | -4.41% |

# CFD fine-tuning & validation

*CFD Fine-tuning observations:*

- Both the adjustments made to fine-tune the CFD methodology proved to be:
  1. Consistent with the *experimental data*
  2. Beneficial for the accuracy of the results where they meant to be so, irrelevant elsewhere

These adjustments have been applied to different valves and compared to experimental data for final validation

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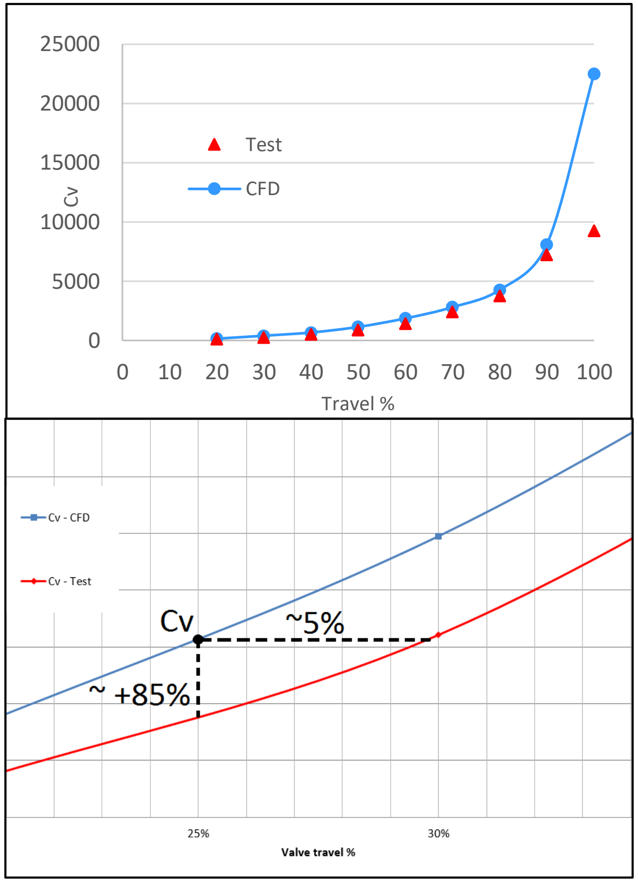
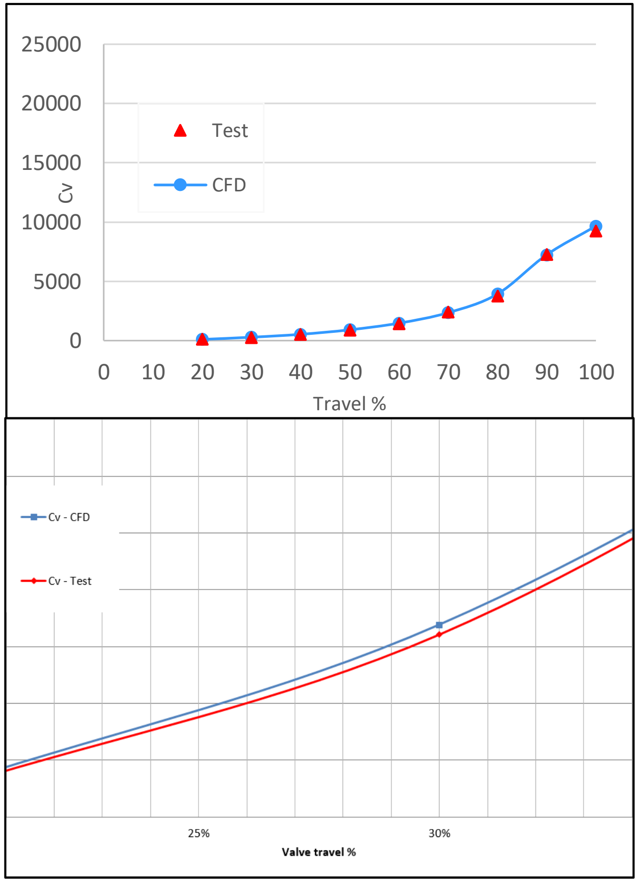
# CFD fine-tuning & validation

## CFD vs. Experimental testing – Before and after

BEFORE




AFTER



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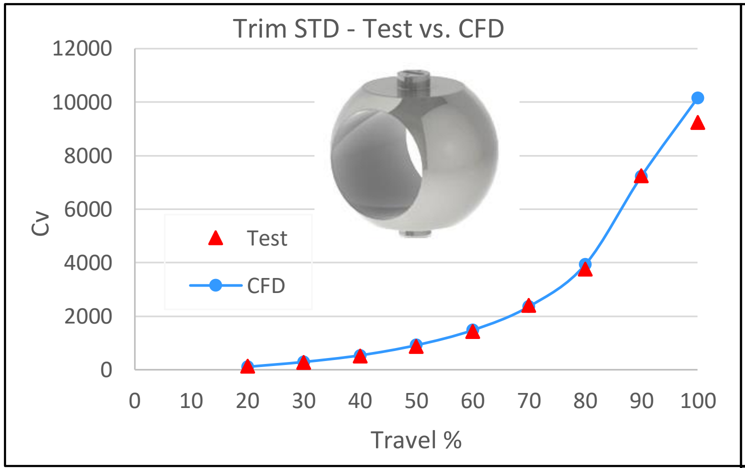
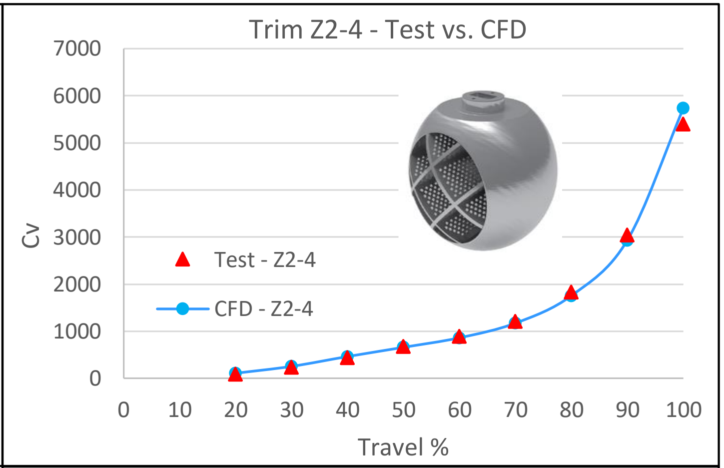
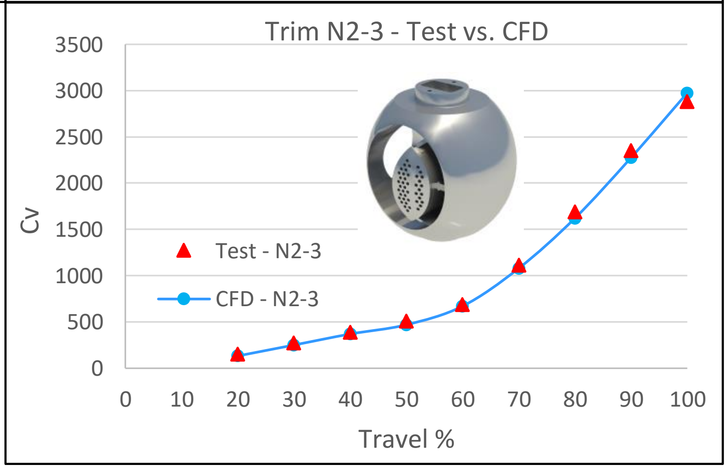
# CFD fine-tuning & validation

## CFD (fine-tuned) vs. Experimental testing – Comparison




***Increased $C_V$ prediction accuracy vs. test data with fine-tuned CFD***



# Extending the experimental results through *validated* CFD methodology

CFD campaign based on a *matrix of simulations*

- Should guarantee *adequate coverage* of the product range
- Should consider *specific product design*

| Trim type | Pressure class: ANSI 600 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10” | 12” | 14” | 16” | 18” | 20” | 24” | 28” | 30” | 32” | 36” |
| **STD** | | ✓ | | | | | ✓ | | | | ✓ |
| **Z1-2** | | ✓ | | ✓ | | | ✓ | | | | |
| **Z2-4** | | ✓ | | ✓ | | | ✓ | | ✓ | | ✓ |
| **N1-3** | | ✓ | | ✓ | | | ✓ | | | | |
| **N2-3** | | ✓ | | ✓ | | | ✓ | | | | |
| **N2-4** | | ✓ | | ✓ | | | ✓ | | | | |

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# Thank you!