Evaluation and effect of the dynamic torque on cage control ball valves

Danilo Barni

SUMMARY

- Ball valve and control ball valve torque during operation
- Torque generated by fluid-dynamic: computational
- Experimental Validation on prototypes
- Size and process scaling
- Conclusions and further action

Reason for fluid-dynamic torque effects review

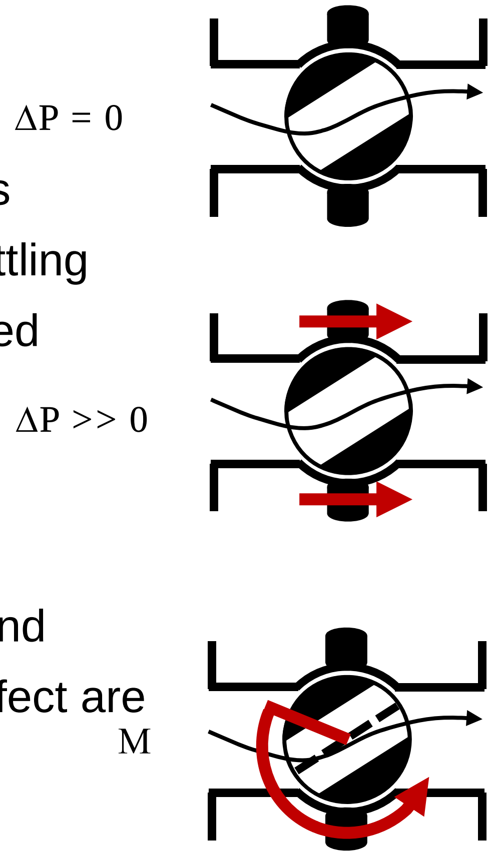
- Actuator sizing (and cost) depends on the valve torque curve;
  - Uncertainties are mitigated by “safety factors” resulting in oversizing or under sizing

- Torque curve during operation for ball-type valves depends on:
  - Static load (friction by assembling tolerances, springs…)
  - Pressure energized load (friction on sealing and bearings area)
    - Very well known and predictable stating the MANY valves produced and validated

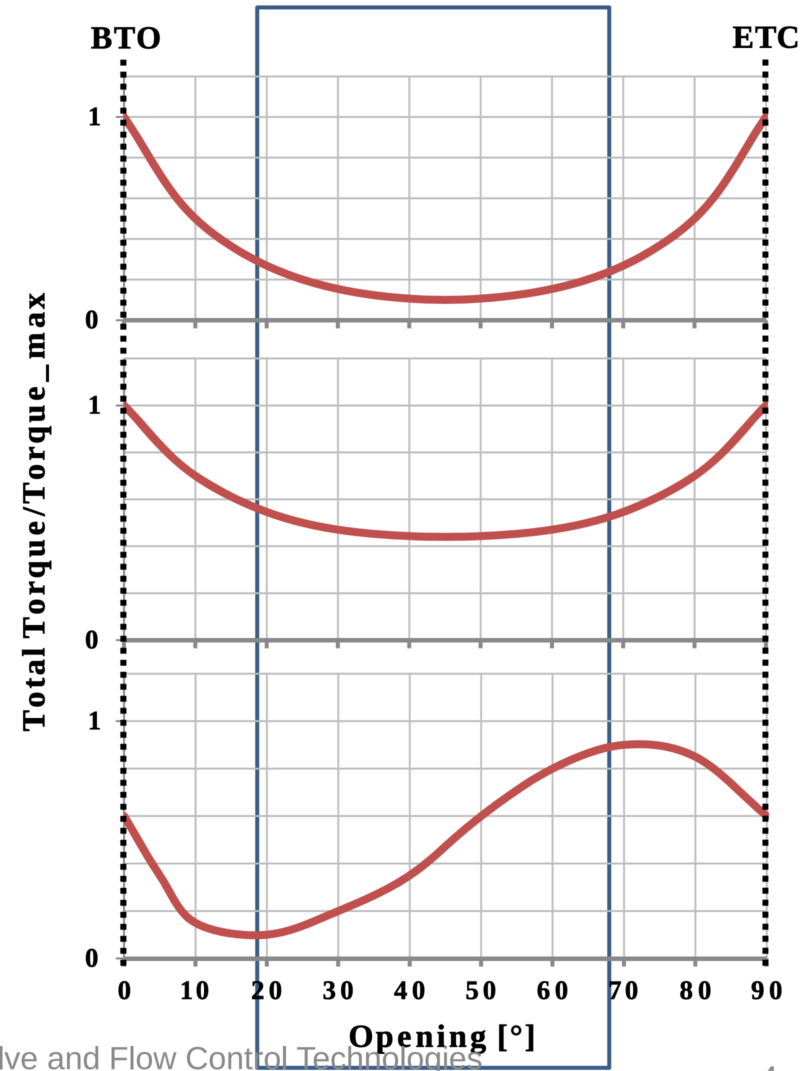
  - Fluid-dynamic load (momentum transfer by the fluid to the internals)
    - This is strongly related to process condition during throttling and <u>could be dominant for Control Valve</u>.
    - Only during throttling (intermediate position)

BALL VALVE (cage) TORQUE CURVE (throttling)

Depending of process condition during throttling torque curve is affected

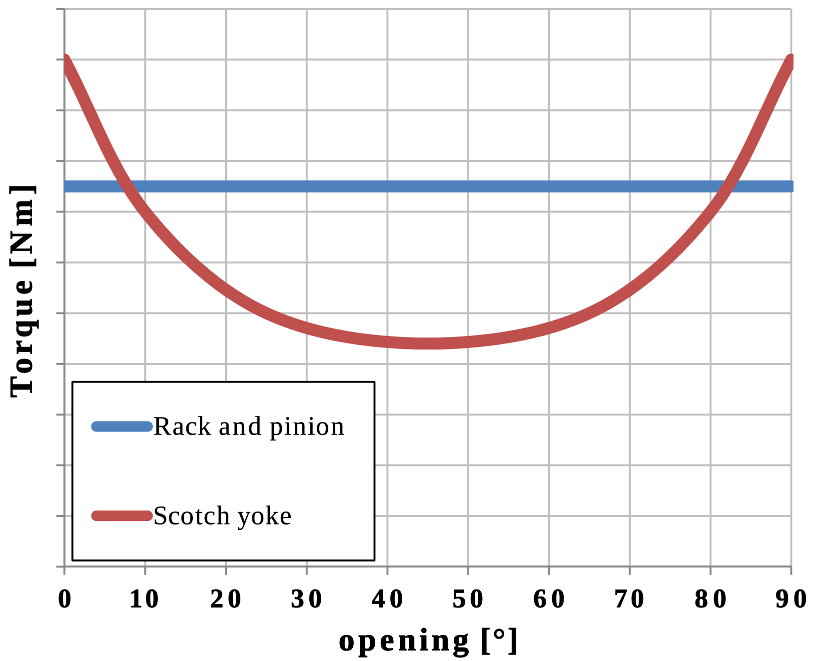


Depending of fluid and process, dynamic effect are affecting the curve

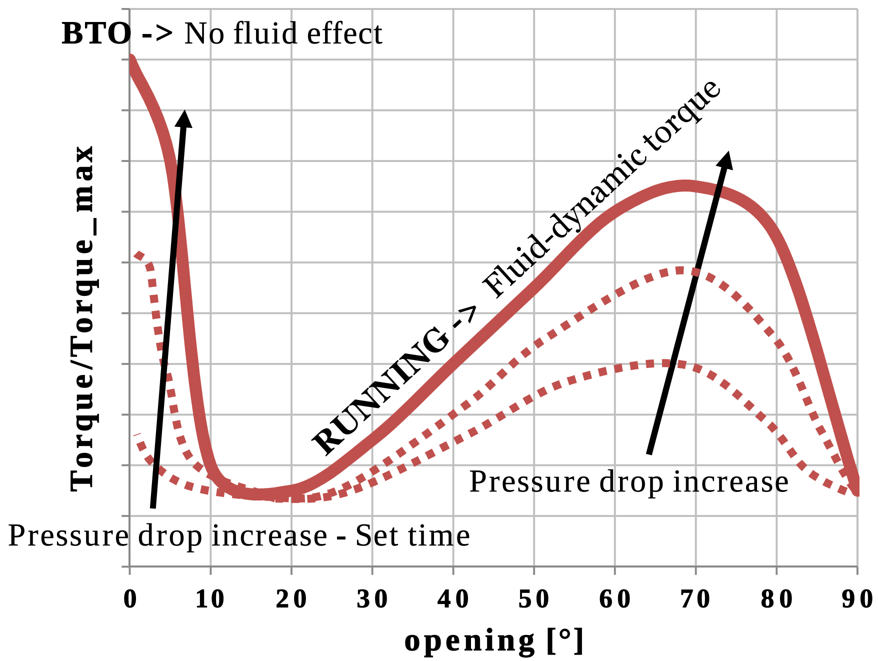


TORQUE CURVE Actuators vs Valves

Typical actuator torque

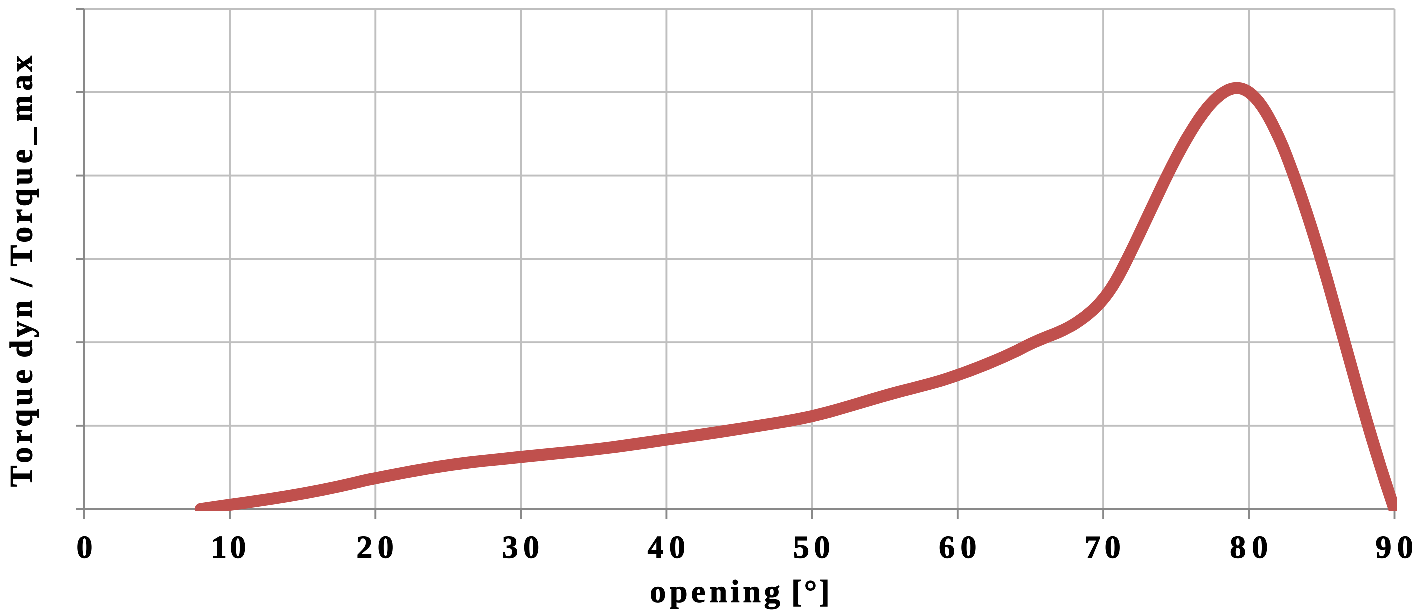


Valve torque with dynamic load



Most critical condition: **process @ constant pressure drop!**

BALL VALVE FLUID-DYNAMIC TORQUE



For a ball valve, the fluid-dynamic torque, has a peak around 80°, while it is almost zero at 90° and at low openings [literature data]

The curve if affected by the expected pressure drop (i.e. flow rate) at the different openings

Internals and trim design of control ball valves are modifying the fluid-dynamic torque curve

METHODOLOGY

- Focusing on dynamic torque effect
  - Prediction by CFD
    - On real trim geometries
    - With different working conditions
    - Scaling rule versus pressure drop and size
  - Validate by experimental set up
    - On same geometries predicted by CFD
    - In very different working condition to mitigate measurement error propagation
    - Scaling rule versus pressure drop and size

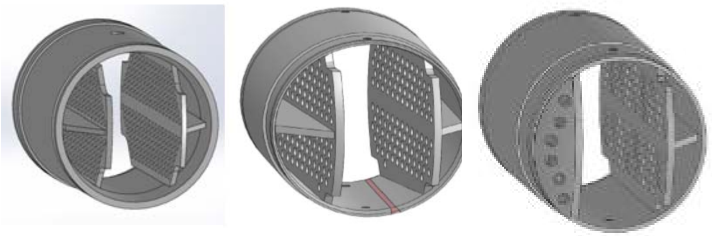
CONTROL CAGE BALL VALVES

Three types of trims for control ball :

- A -> two perforated plates
- B -> two offset perforated plates
- C -> two perforated plates and a partial resistor

Two valve size were considered:

- 3''
- 8''



CFD analysis

CFD MODEL FORMULATION

- Fluid – dynamic torque is the result of the pressure on he valve “movable” internals.

- Pressure field is computed by CFD supposing linear (no cavitation/no choke) working condition

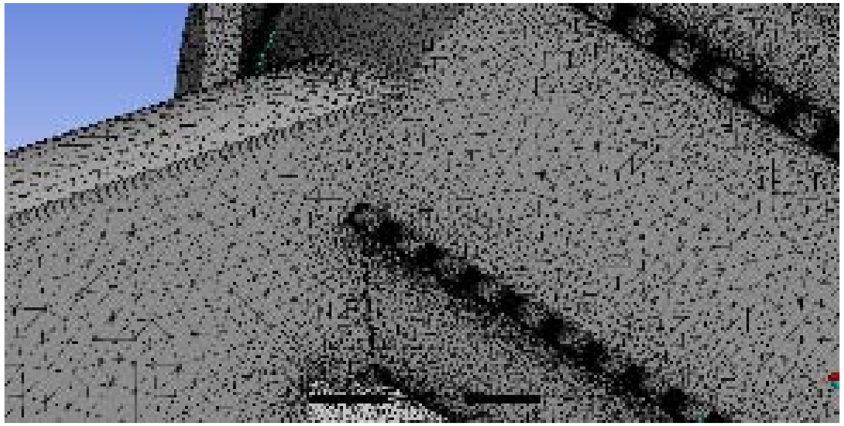
- Pressure field is integrated versus geometry to computed the torque generation

- Scaling versus actual working condition is managed by scaling the pressure field

CFD Flow - Dynamic torque

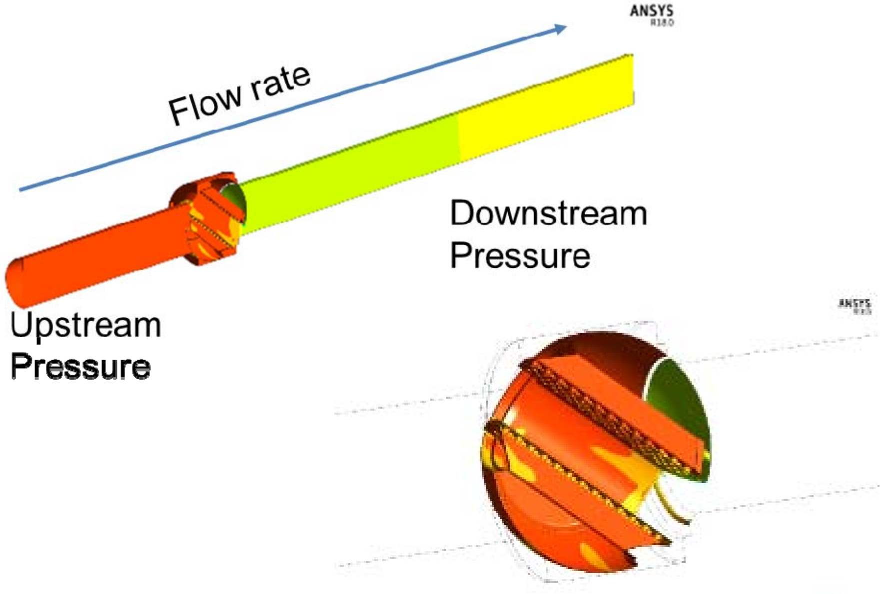
MODEL

- Use as real as possible geometry focusing on detail.
- Some geometry feature are affecting the results even if look s like to be negligible



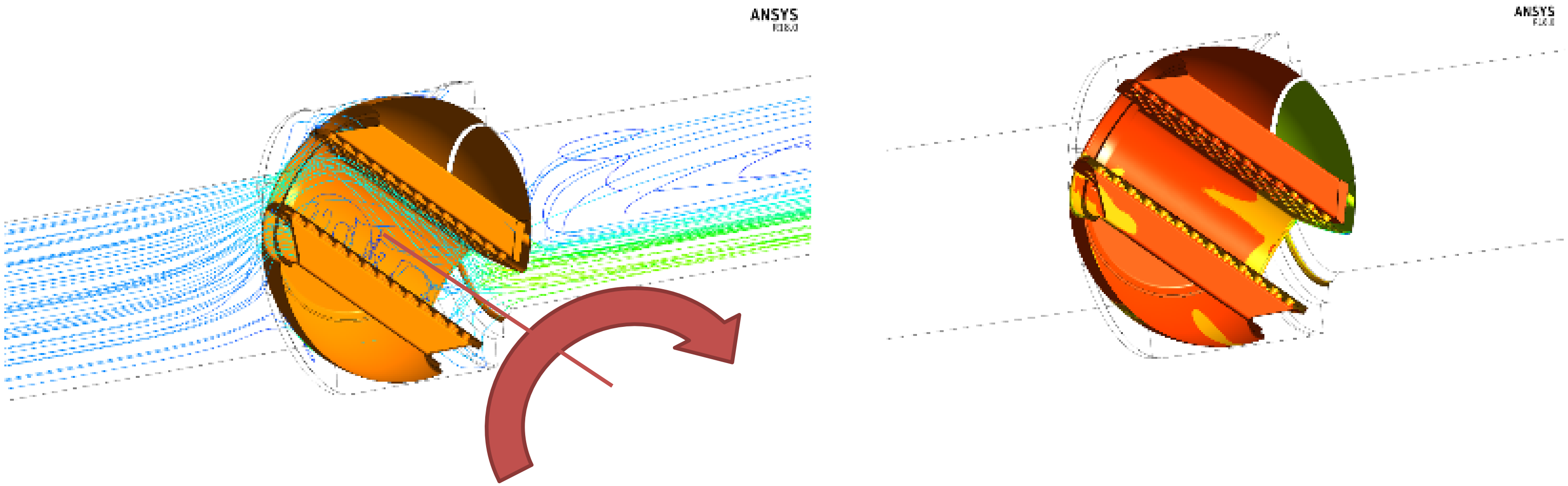
PROCESS

- Calculate pressure field given by the working condition.
- Compute flow coefficient and cavitation index for proper pressure scaling



INDUSTRIALVALVESUMMIT

CFD Flow - Dynamic torque - CALCULATION



- Pressure field generated by the impinging fluid on the affected internals of the valve is integrated versus the stem axis
- Result is normalized versus CFD imposed process conditions.

Experimental setup

Experimental MODEL FORMULATION

- The total torque (**T_{total}**) is composed by a frictional part (**$T_{friction}$**) and a fluid-dynamic part (**T_{fluid}**):

  $$T_{total} = T_{friction} + T_{fluid};$$

- **$T_{friction}$** is composed by a constant part and a pressure loaded part (A + DP x B)
  - It is alwasys opposing the movement

- T_{fluid} depend on the pressure drop
  - direction is independent to the movement

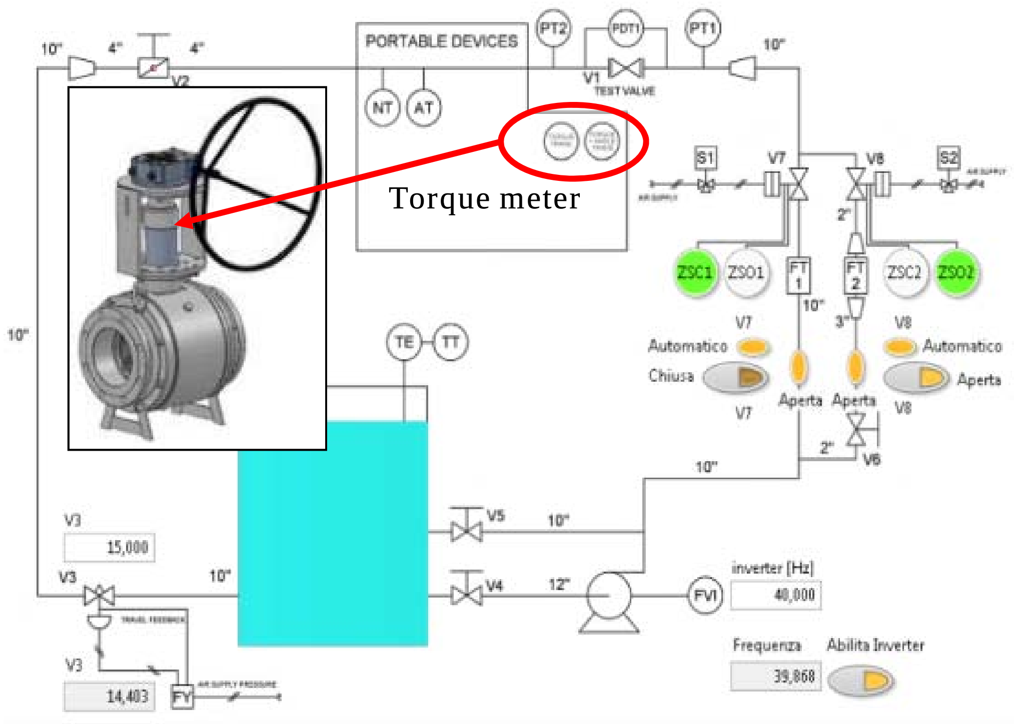
- Experimentally by measuring **$T_{total\_to\_open}$** and **$T_{total\_to\_close}$** also the **T_{fluid}** can be calculated:

  $$T_{fluid} = \frac{T_{total\_to\_open} + T_{total\_to\_close}}{2};$$

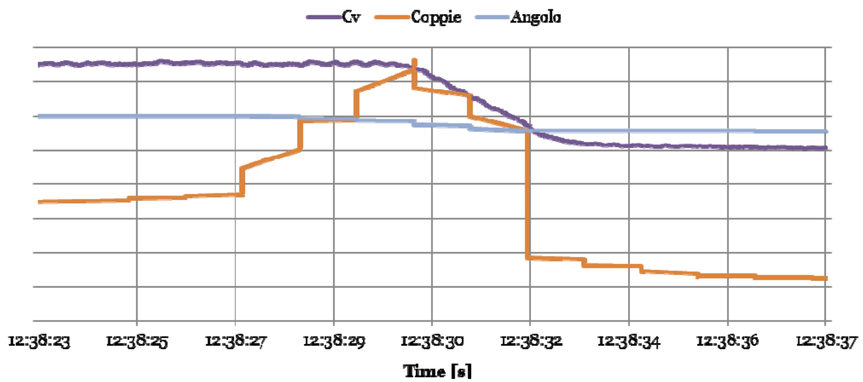
- Different working condition (in fluid dynamic equivalent region) are compared using a fluid-dynamic torque coefficient (**CT_{fluid}**):

  $$CT_{fluid} = \frac{T_{fluid}}{\Delta P},$$ where ΔP = pressure drop

EXPERIMENTAL SETUP AND INSTRUMENTS



- During measurement the time history of the transducers and computed variables are FULLY recorded by the data acquisition system for offline data analysis.
- Semi automatic data analysis to catch the relevant information from each time history results.
- TWO DIFFERENT EXPERIMENTAL METHOD (results shows for one trim/size)



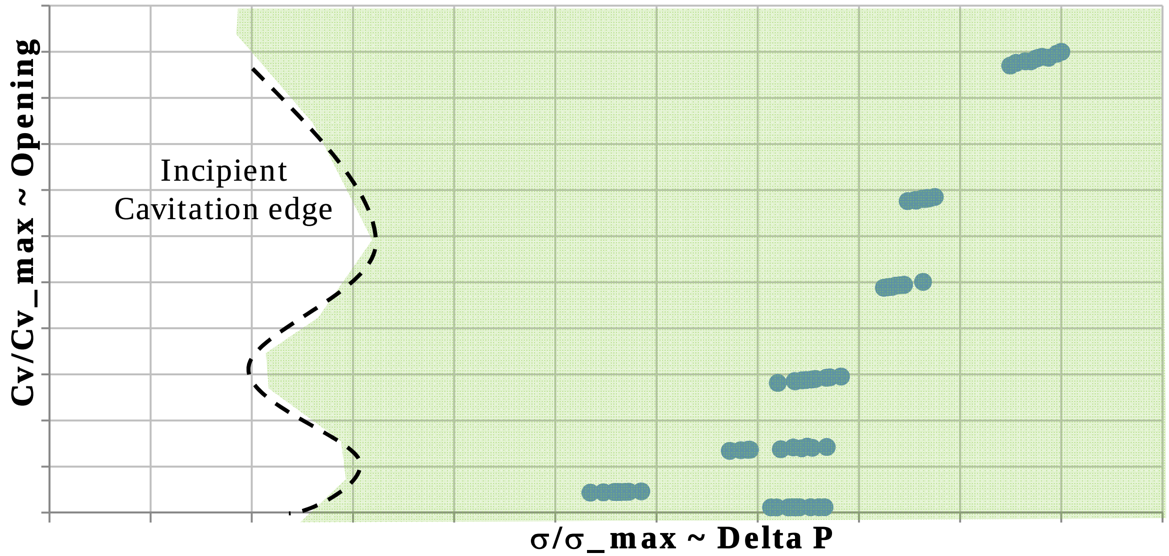
Fixed travel torque

Configuration: 8” type C

Fit in one position (angle)
Select working condition
Measure the instantaneous TO OPEN
Measure the instantaneous TO CLOSE

Process working condition are not changing
Measurement strongly affected by tolerances

WORKING CONDITION SELECTION



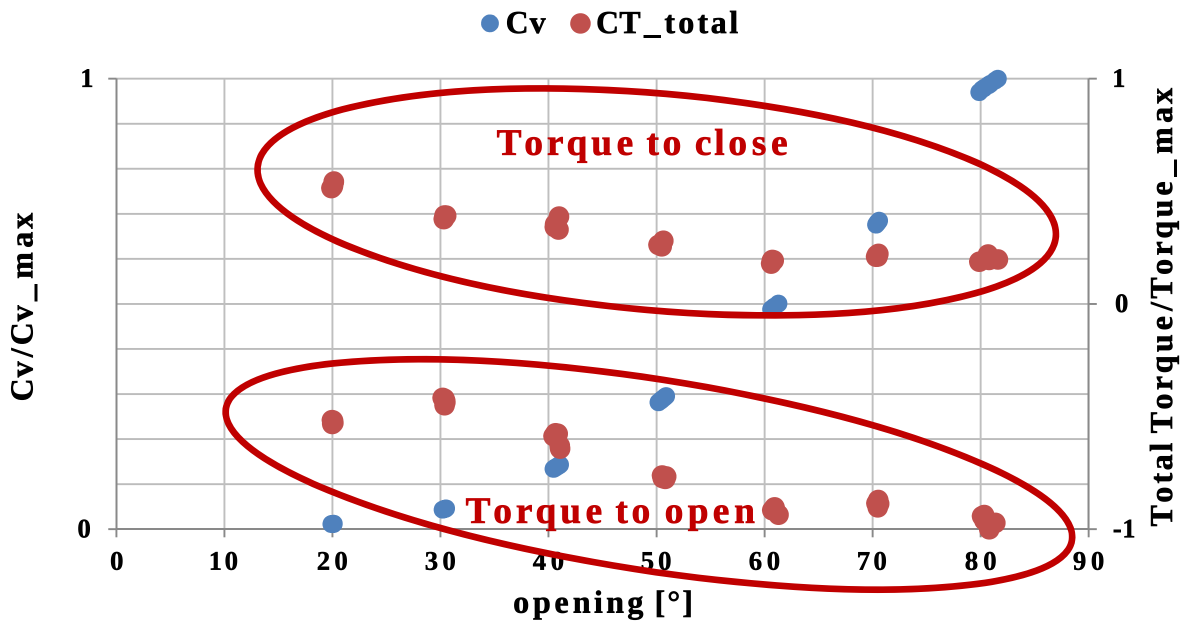
- At each angle need to select pressure drop and flowrate to guarantee out of cavitation effect

- Selected non-cavitating conditions ($\sigma > \sigma i$)
  - Need to know (measure) the valve incipient cavitation index (σi);
- Impose very small valve rotation -> just till override the static friction;

- Repeatability of σ value = ± 2.5% guarantee accurate results
- Constant upstream pressure @ 6.5 barG ± 1% to guarantee accurate results

High accuracy on torque results!

TORQUE TO OPEN vs TORQUE TO CLOSE



- Acquisition of couples of torque data
  - to open direction to close direction
  - at the same working conditions;
  - repeat at different working condition to improve statistics

- Normalize the working condition of different measurement to compare
- GAP (mean) within “top open” and “to close” is driven by the fluid-dynamic torque

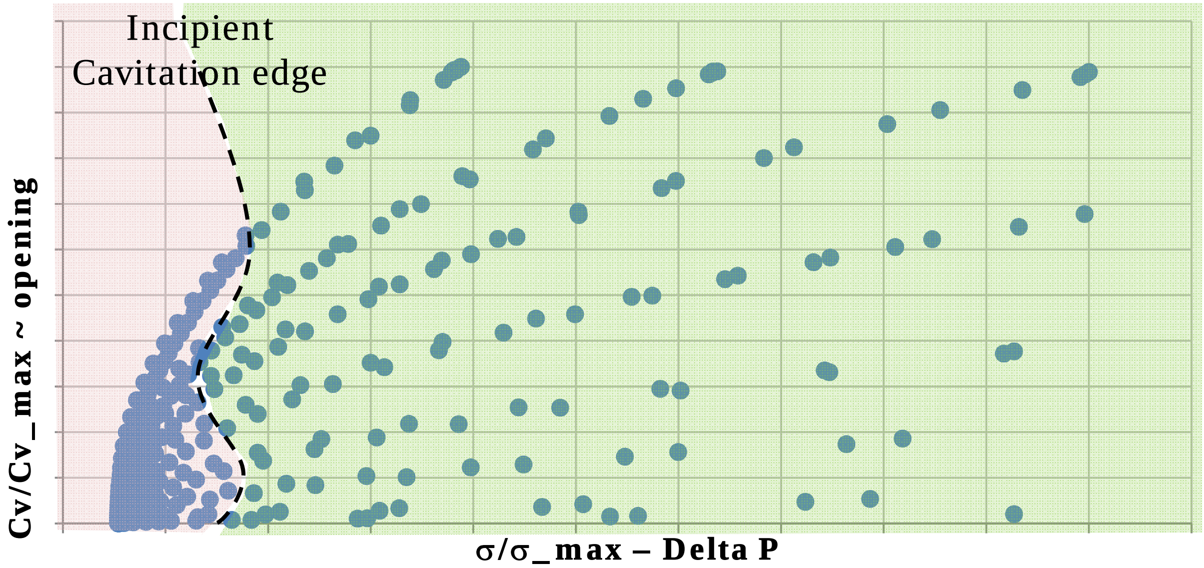
Continuous travel torque

Configuration: 8” type C

Fit in one position (angle)
Select working condition
Measure full torque stroke TO OPEN
Measure full torque stroke TO CLOSE

Process working condition are changing
Measurement less affected by tolerances

WORKING CONDITION SELECTION

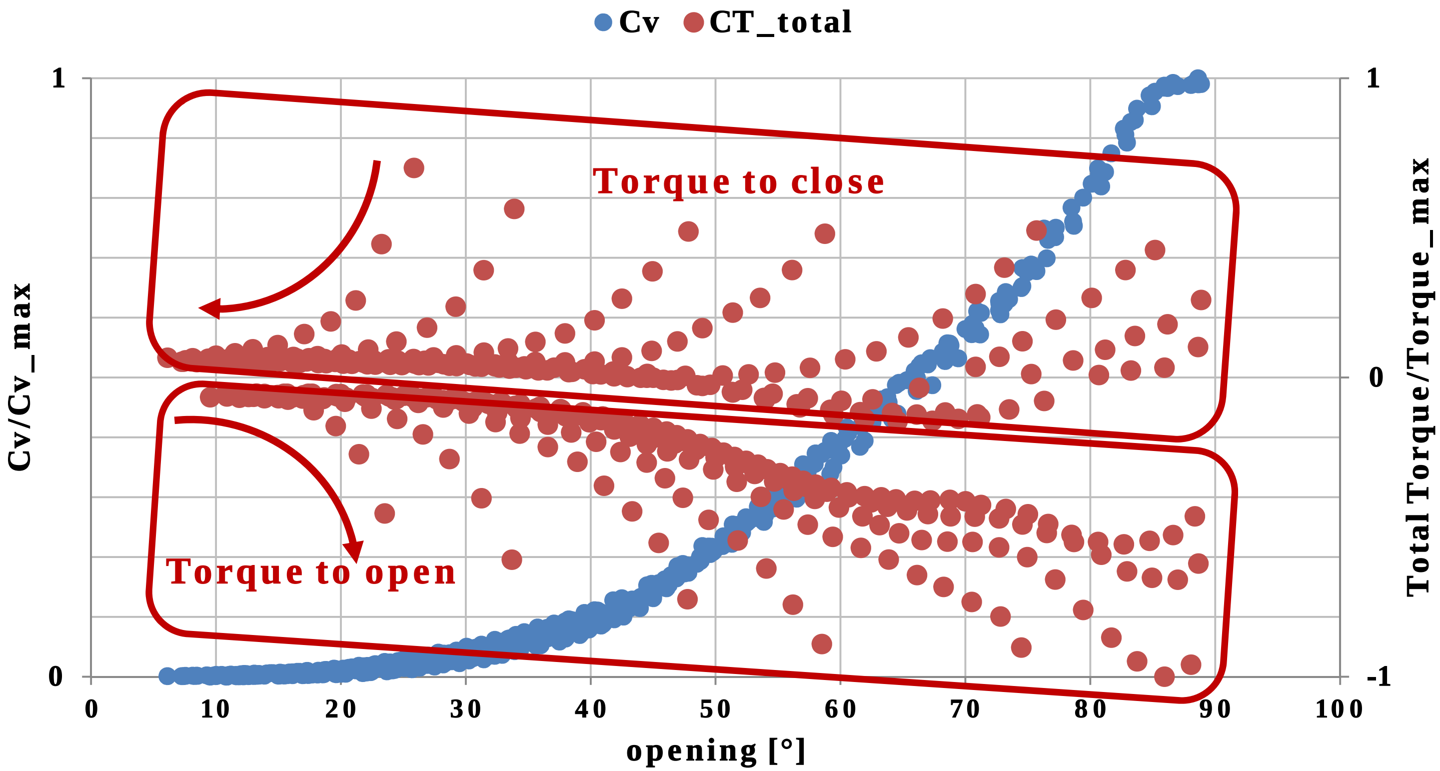


- Data acquired in cavitating and non-cavitating conditions;
  - Need to know (measure) the valve incipient cavitation index (σi);

- Complete valve rotation -> o° ÷ 90°;
- Transient condition is affecting the measurement error.
- Non-constant upstream pressure during measuremnt -> 5 ÷ 8 barG.

Incipient Cavitation effect included, but lower accuracy on torque results!

TORQUE TO OPEN vs TORQUE TO CLOSE



- Acquisition of couples of torque data,
  - same start/stop working conditions
- Due to continuous changes in process conditions -> data to close direction and to open direction are affected by treansient effect

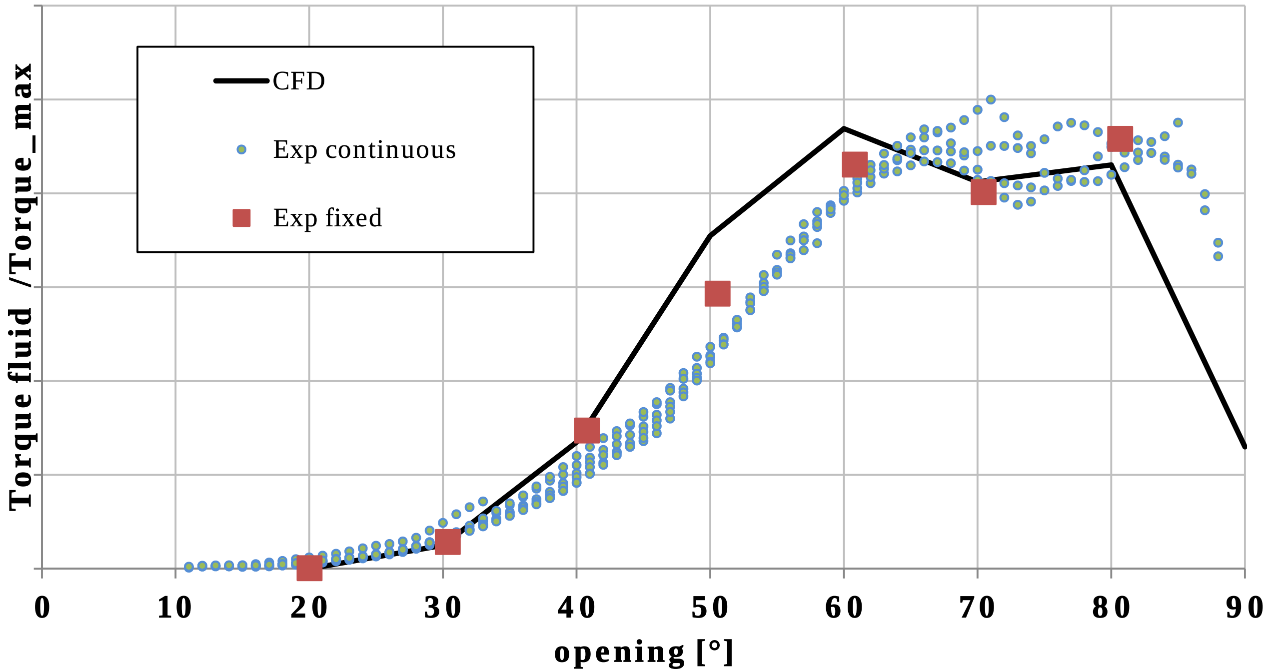
- Gap (dynamic effect) during cavitation transition is reducing but the “mean” is not afffected

RESULTS

Experimental vs CFD

- Configuration 8'' type C

EXPERIMENTAL vs CFD FLUID-DYNAMIC TORQUE



- Results show good correlation between experimental and CFD results;
- In both the methods, the fluid-dynamic torque is almost zero till 30°, while shows two peaks around 60° and 80°.

- Continuous travel method allows to completely describe the torque curve, but is less accurate than the fixed travel method, in particular near the torque peak.

RESULTS

Scaling versus size

SIZE SCALING on OVERALL RESULTS

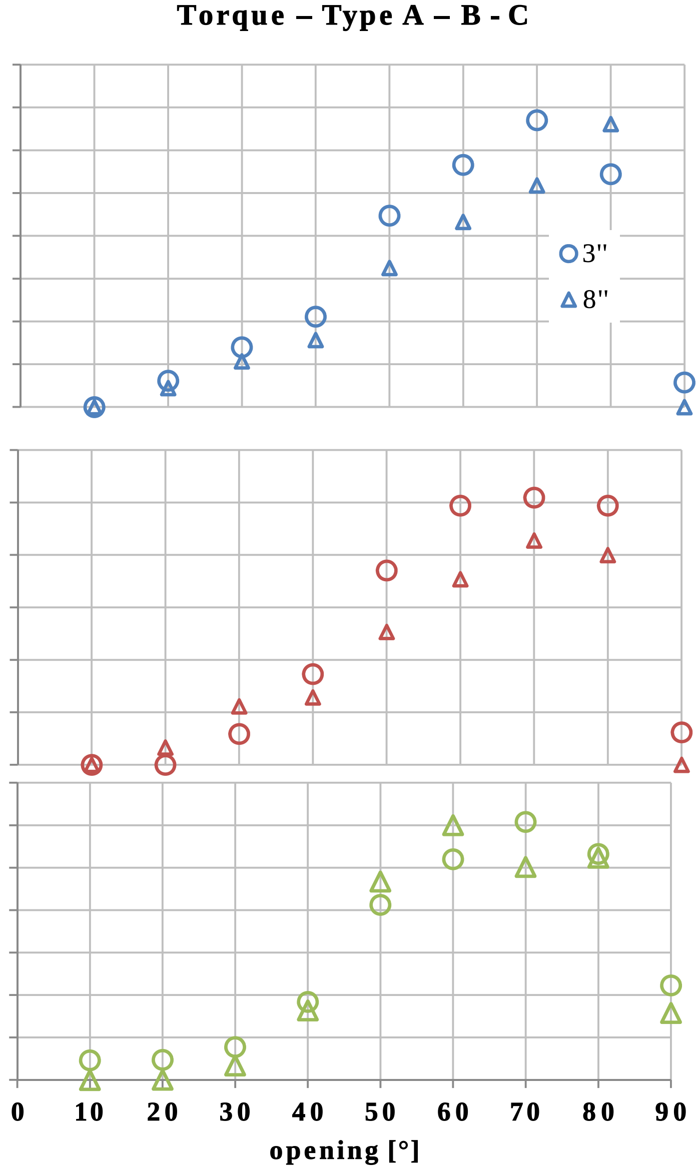
- CFD and measurements were run for the different proposed size (3” , 8”) and trim (A, B ,C)
- All results are validated.

- Comparison of result by size scaling rule
  - Trim Diameter : D^3
- 20% different is reported versus scaling of > 2X

- Control cage ball valves shows torque coefficient peaks in the area of 50°-70°

- <u>Trim geometry is affecting the shape and peak values of the torque coefficient</u>.

- <u>Torque effect is depending on process operating condition</u>



CONCLUSIONS

- Torque effect generated by fluid-dynamic load has been investigated and analyzed (what is affecting what)
- CFD results and experimental data are well matching giving confidence in design by analysis methodology.
- Process condition are mandatory for proper full valve torque definition during sizing.

- Trim design can be optimized for low torque effects without “damaging” the process performance characteristics.

ACKNOWLEDGEMENT

- The work was done with the strong support of
  - Prof. Stefano Malavasi – Politecnico di Milano
  - Marco Rossi – Politecnico di Milano
  - Filippo Bossi – Pibiviesse
  - Valerio Garbarino – Pibiviesse
  - Marco Spadaccino – Pibiviesse
  - Bongiovanni Lorenzo - Pibiviesse