4th DualSPHysics Users Workshop

Simulating an Archimedes Screw Pump with DualSPHysics

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Date: 23 October, 2018

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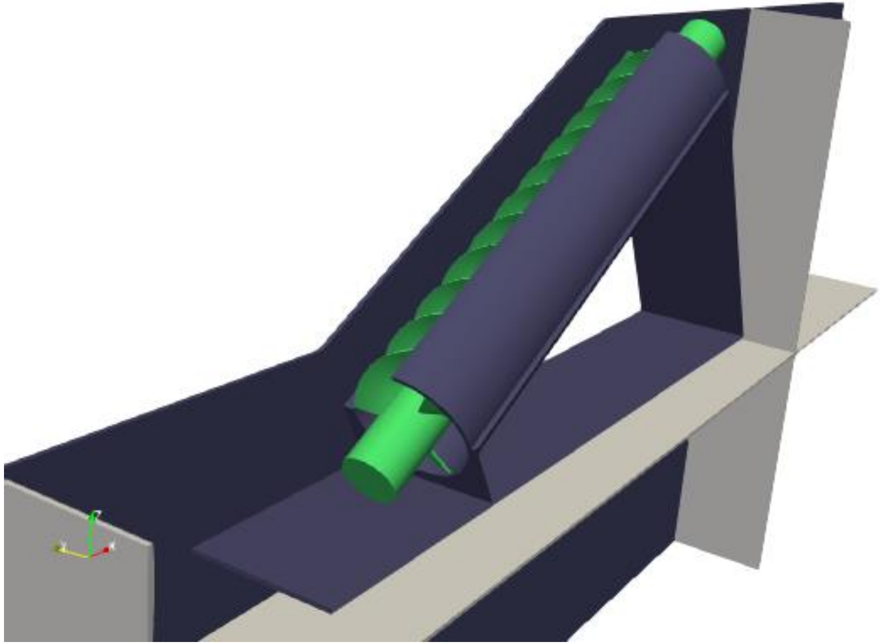
Introduction

- The case: an Archimedes Screw Pump
- Simulation settings
- Results
- Conclusions

The case: an Archimedes Screw Pump

- Real life engineering project for a fairly large water pumping station for agricultural irrigation.
- Current convention is to estimate the mass flow rate with analytical methods:
    - 1st step: 3D CAD volume analysis
    - 2nd step: Apply a factor, based on experimental results
- DualSPHysics was chosen as an experimental tool to assess if the analytical calculations are accurate enough or not.

The case: an Archimedes Screw Pump



- 13.5 m for the axle length
- 12.2 m for the screw length
- 3 screw blades, 8mm thick
- Inclination: 29º
- Splash guard: design 40º, used 90º
- Rotation speed: 27.3 RPM

Simulation settings

- DualSPHysics4 v4.2.068 (09-08-2018), pre-built GPU version
- NVIDIA GeForce GTX 1070 Ti, 8GiB of RAM
- Particle distribution *dp*: 0.05m
- Initial RAM occupancy: 2641214 particles, 575 MB on GPU and 227 MB on CPU
- 60s simulation took roughly 38h to run

Simulation settings

```xml
<constantsdef>
    <lattice bound="1" fluid="1" />
    <gravity x="0" y="0" z="-9.81" comment="Gravitational acceleration" units_comment="m/s^2" />
    <rhop0 value="997.45" comment="Reference density of the fluid" units_comment="kg/m^3" />
    <hswl value="0" auto="true" comment="Maximum still water level to calculate speedofsound using coefsound" units_comment="metres (m)" />
    <gamma value="7" comment="Polytropic constant for water used in the state equation" />
    <speedsystem value="0" auto="true" comment="Maximum system speed (by default the dam-break propagation is used)" />
    <coefsound value="15" comment="Coefficient to multiply speedsystem" />
    <speedsound value="0" auto="true" comment="Speed of sound to use in the simulation (by default speedofsound=coefsound*speedsystem)" />
    <coefh value="1.0" comment="Coefficient to calculate the smoothing length (h=coefh*sqrt(3*dp^2) in 3D)" />
    <cflnumber value="0.2" comment="Coefficient to multiply dt" />
</constantsdef>

<parameters>
    <parameter key="PosDouble" value="1" comment="Precision in particle interaction 0:Simple, 1:Double, 2:Uses and saves double (default=0)" />
    <parameter key="StepAlgorithm" value="2" comment="Step Algorithm 1:Verlet, 2:Symplectic (def=1)" />
    <parameter key="VerletSteps" value="40" comment="Verlet only: Number of steps to apply Eulerian equations (def=40)" />
    <parameter key="Kernel" value="2" comment="Interaction Kernel 1:Cubic Spline, 2:Wendland (def=1)" />
    <parameter key="ViscoTreatment" value="2" comment="Viscosity Formulation 1:Artificial, 2:Laminar+SPS (def=1)" />
    <parameter key="Visco" value="9.3378e-7" comment="Viscosity value" units_comment="m^2/s"/>
    <parameter key="DeltaSPH" value="0.1" comment="DeltaSPH value, 0.1 is the typical value, with 0 disabled (def=0)" />
```

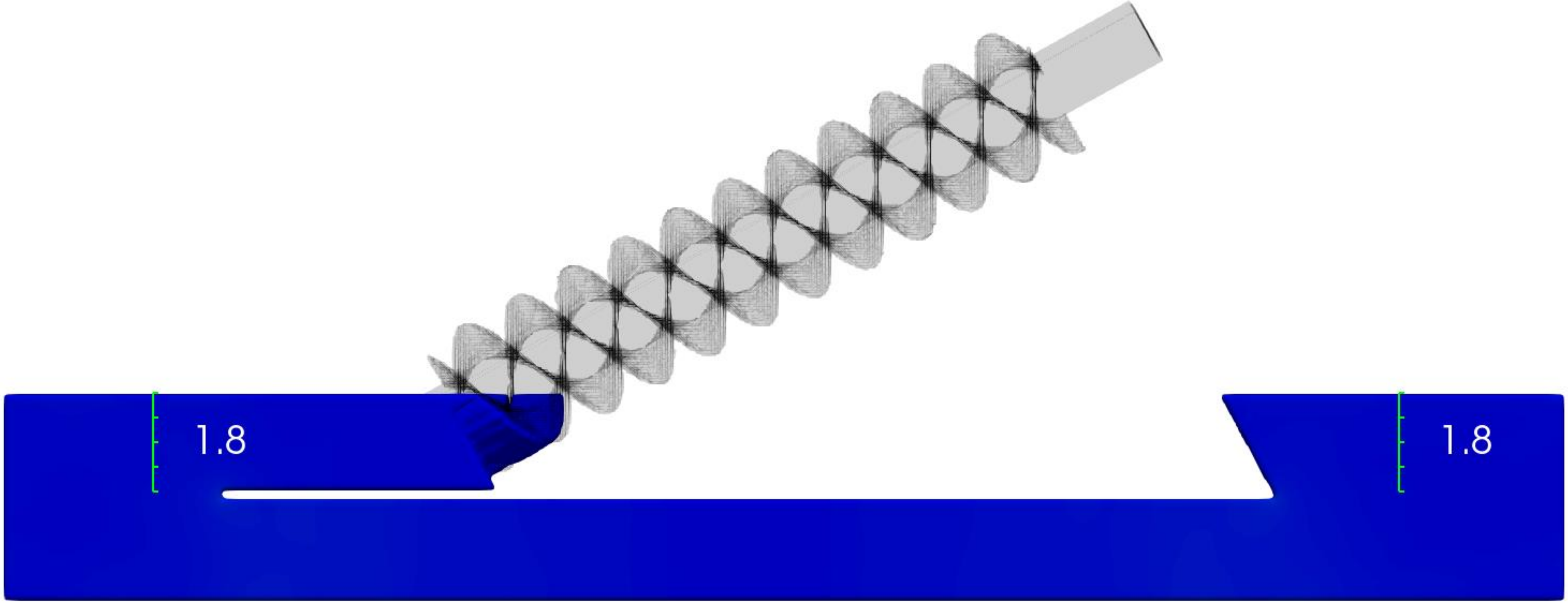
Simulation settings

```xml
<parameter key="Shifting" value="3" comment="Shifting mode 0:None, 1:Ignore bound, 2:Ignore fixed, 3:Full (default=0)" />
<parameter key="ShiftCoef" value="-2" comment="Coefficient for shifting computation (default=-2)" />
<parameter key="ShiftTFS" value="2.75" comment="Threshold to detect free surface. Typically 1.5 for 2D and 2.75 for 3D (default=0)" />
<parameter key="RigidAlgorithm" value="1" comment="Rigid Algorithm 1:SPH, 2:DEM (default=1)" />
<parameter key="FtPause" value="0.01" comment="Time to freeze the floatings at simulation start (warmup) (def=0)" />
<parameter key="DtIni" value="0.0001" comment="Initial time step" />
<parameter key="DtMin" value="0.0000001" comment="Minimum time step (def=0.00001)" />
<parameter key="DtAllParticles" value="0" comment="Velocity of particles used to calculate DT. 1:All, 0:Only fluid/floating (default=0)" />
<parameter key="TimeMax" value="60.0" comment="Time of simulation" />
<parameter key="TimeOut" value="0.1" comment="Time between output files" />
<parameter key="IncZ" value="1.0" comment="Increase of Z+" />
<parameter key="PartsOutMax" value="1" comment="%/100 of fluid particles allowed to be excluded from domain (default=1)" units_comment="decimal" />
<parameter key="RhopOutMin" value="700" comment="Minimum rhop valid (default=700)" units_comment="kg/m^3" />
<parameter key="RhopOutMax" value="1300" comment="Maximum rhop valid (default=1300)" units_comment="kg/m^3" />
</parameters>
```

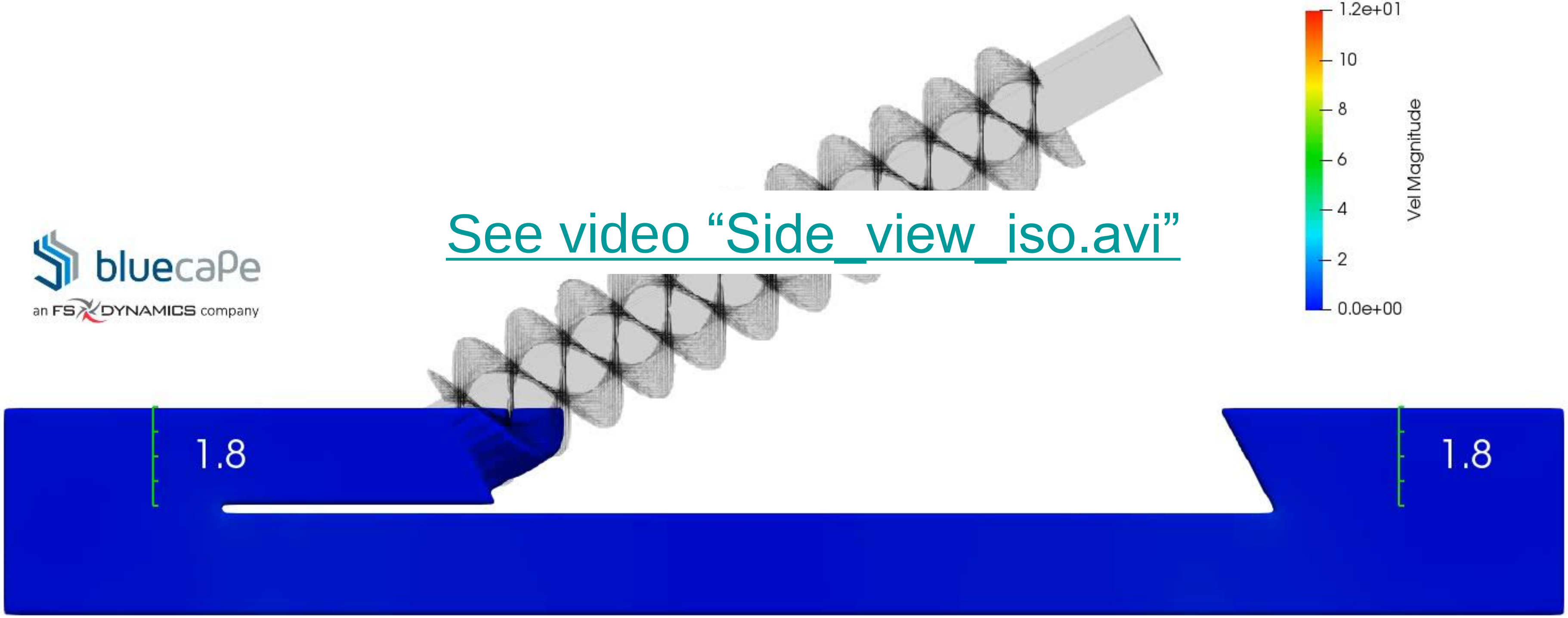
Simulation settings

```
<motion>
    <objreal ref="0">
        <begin mov="1" start="0" finish="1010.0" />
        <mvrotace id="1" duration="10.0" next="2" anglesunits="radians">
            <ace ang="0.28588493" units_comment="rad/s2" />
            <velini ang="0"  units_comment="rad/s" />
            <axisp1 x="-2.02349" y="0" z="0.73239" units_comment="m" />
            <axisp2 x="11.70804" y="0" z="8.3439" units_comment="m" />
        </mvrotace>
        <mvrot id="2" duration="1000.0" next="2" anglesunits="radians">
            <vel ang="2.8588493" units_comment="rad/s" />
            <axisp1 x="-2.02349" y="0" z="0.73239" units_comment="m" />
            <axisp2 x="11.70804" y="0" z="8.3439" units_comment="m" />
        </mvrot>
    </objreal>
</motion>
```

Simulation settings



Time: 0.0s



See video “Side_view_iso.avi”

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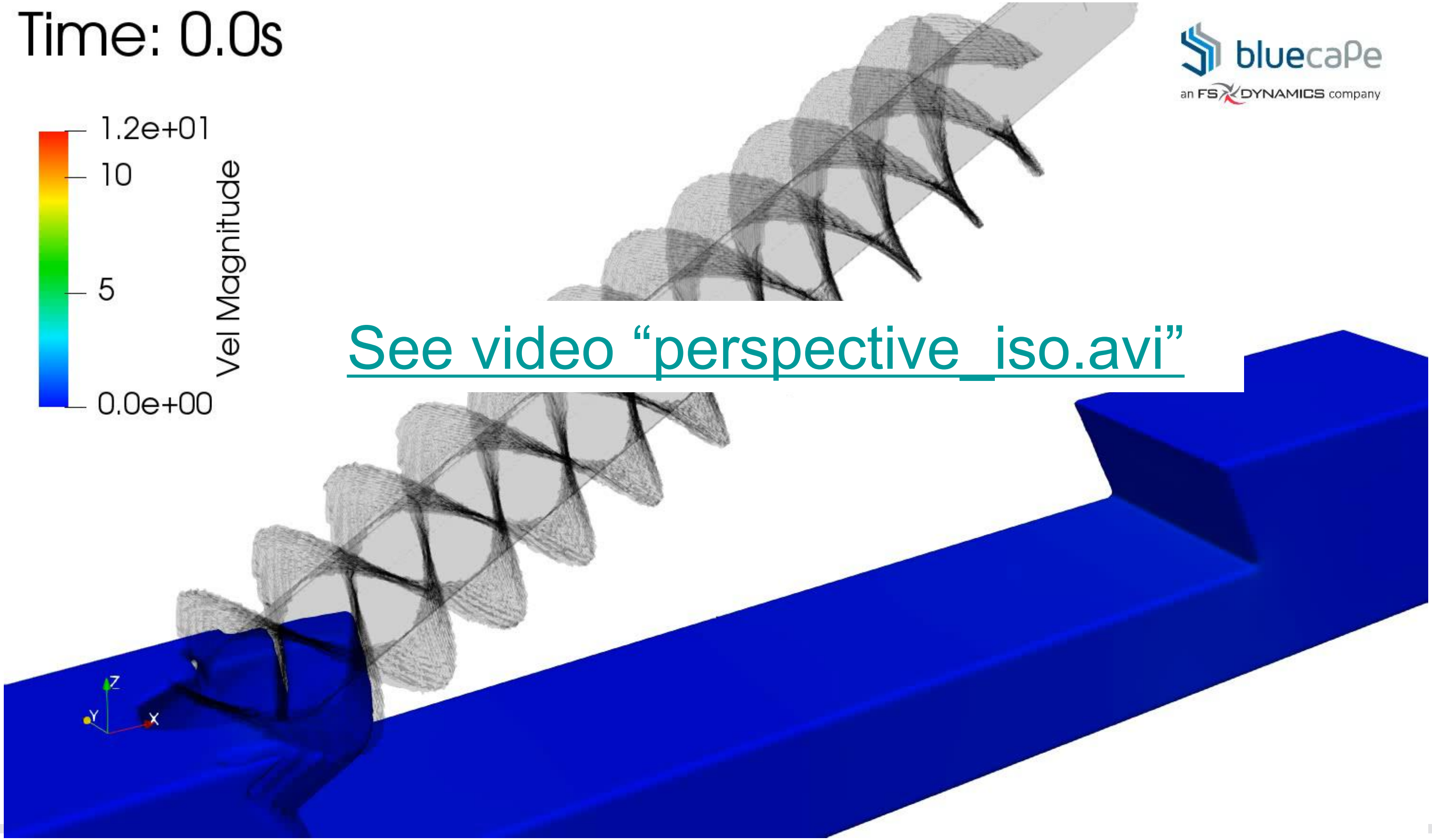
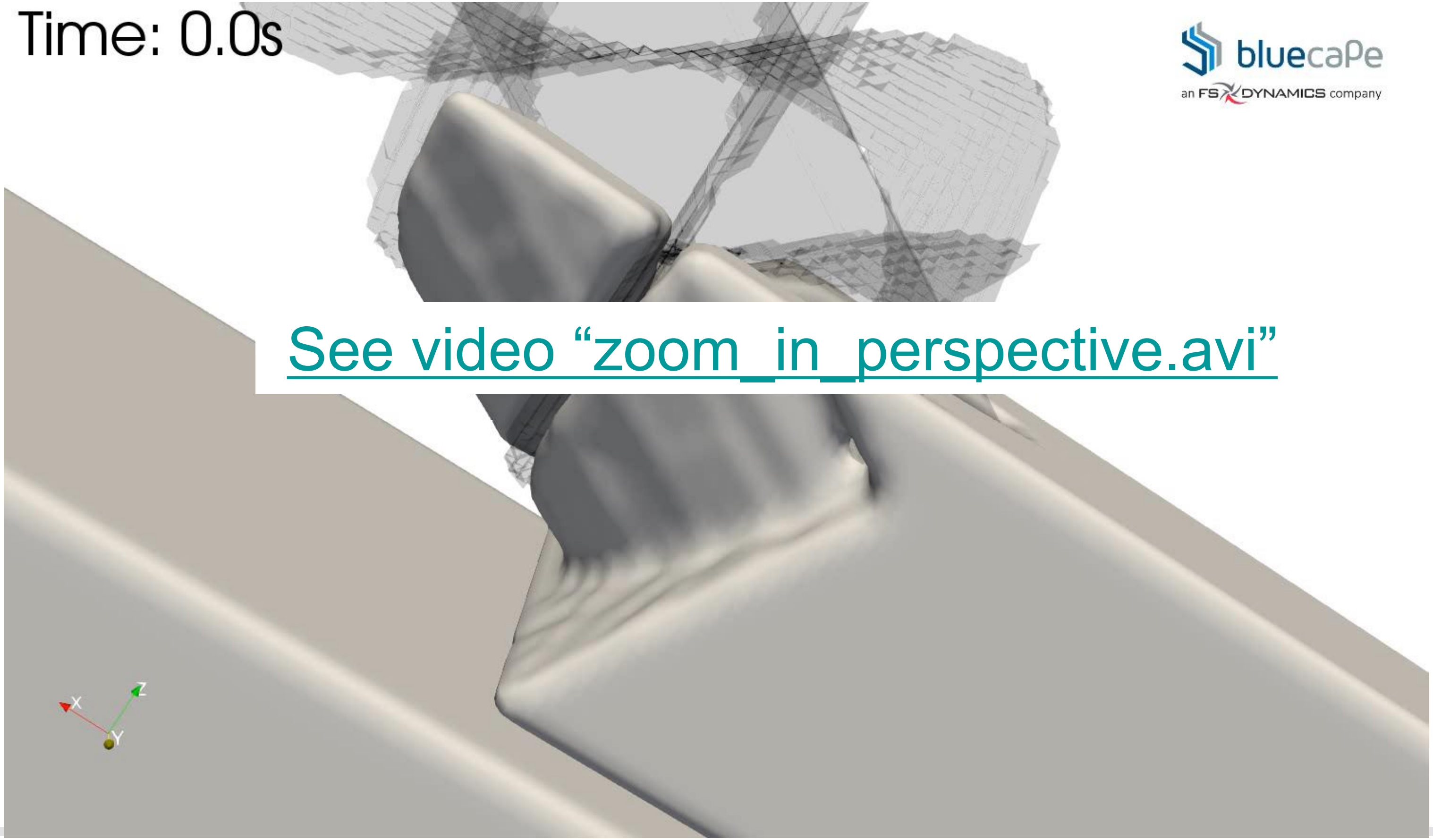
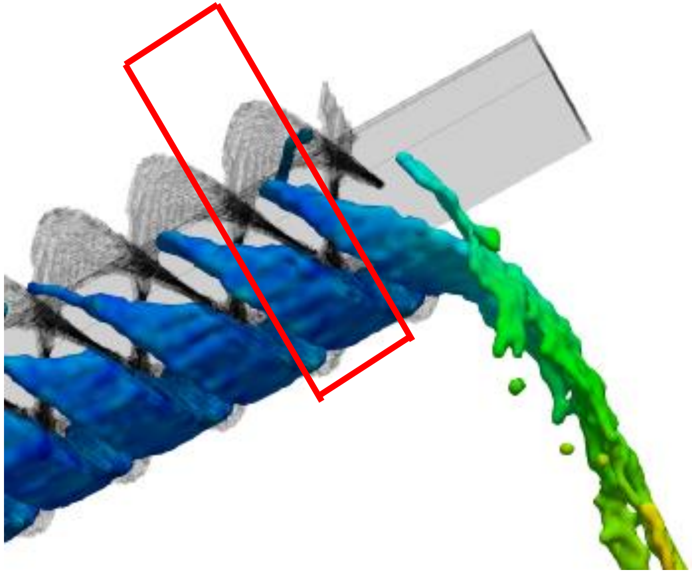


See video "perspective_iso.avi"



See video "zoom_in_perspective.avi"

Results



- The objective was to measure the mass flow rate.
- Either we would to code our own utility to calculate this…
- Or we could use a sampling box, shown on the left, and correlate with the rotation speed.
- We ended up not doing this, given the missing volume.

Conclusions

- Inlet boundary conditions from DualSPHysics 4.4 are very much welcome!
- Due to hydrophobic effect on moving bounds on these scales, a new implementation is needed (it’s even worse at *dp=0.0005m*)
- We need a new utility to (more accurately) calculate the mass flow rate
- Hermetic bound particles would be very helpful (we had 5-15cm thick blades, instead of 8mm)

Conclusions – post-workshop

- The hydrophobic effect on moving bounds should be reduced if we correct the speed of sound value.
  - The dynamic boundary conditions treatment in DualSPHysics 4.3/4.4 should also help minimize this effect.
- The FlowTool utility present in DualSPHysics 4.2 should allow us to calculate the mass flow rate.
- Plugging in holes on the surfaces could possibly be done by following the instructions given in the DualSPHysics 4.2 Users Guide, specifically the example **RedrawGenCase**.