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form presents:

APPLICATION OF CAVITATION MODELS TO STUDY A REAL CASE OF DIE EROSION

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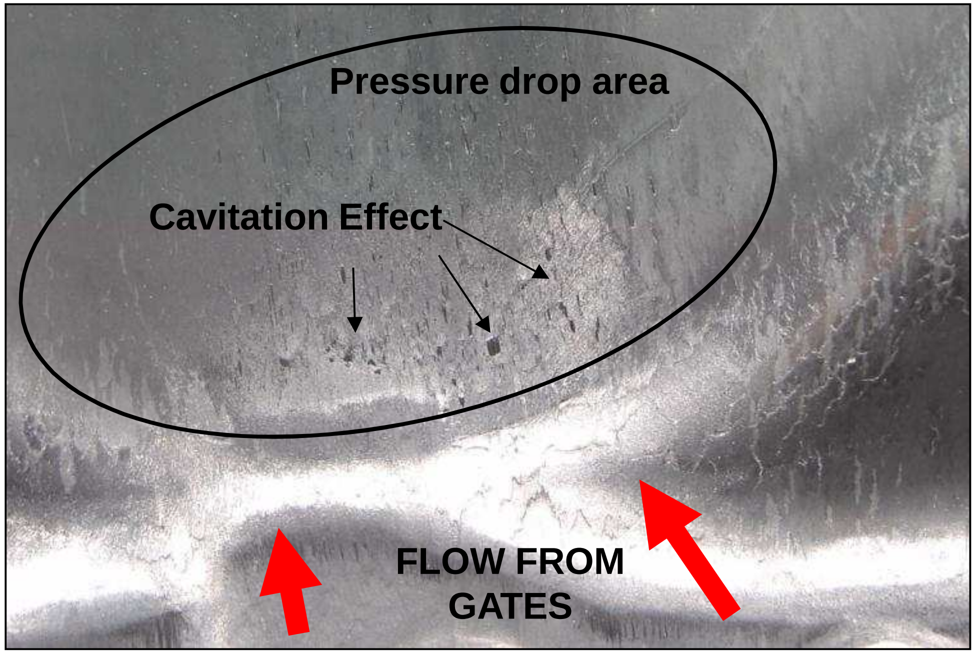
Cavitation in HPDC

Cavitation in HPDC

- ***We have die erosion during high-pressure die casting filling, where metal pressure often drops several atmospheres below the vapor pressure in areas of very fast flow, usually near the gates, causing the metal to cavitate.***



Cavitation models available in Flow3d-cast

Cavitation Potential model

It predict the likelihood of cavitation, without actually introducing bubbles into the flow

The model evaluates the integral over time of the difference between the Cavitation pressure and the local fluid pressure:

$$S = \int_0^t \max(0, PCAV - p(ijk))dt$$

Advantages:

+ ***lower computational time (scalar variable) than the Active model***
+ ***"hot spots" indicates clearly small critical areas***

Disadvantages:

- ***This result shows where there is the possible nucleation of bubbles but not where they will implode causing damage***
- ***It's an integral over time then it could be influenced by low peak of pressure***

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Cavitation models available in Flow-3d cast

Cavitation Passive model - Simplified model

Voids are not opened, but the cavitation volume fraction is predicted and transported throughout the computational domain

It simulates the generation of cavitation bubbles wherever the local fluid pressure drops below the Cavitation pressure.

With the simplified model the rate of generation is controlled by the Characteristic time for formation

Advantages:

+ ***still lower computational time (scalar variable) than the Active model***
+ ***"hot spots" indicates clearly small critical areas***
+ ***the cavitation volume fraction is tracked as it is advected throughout the domain***

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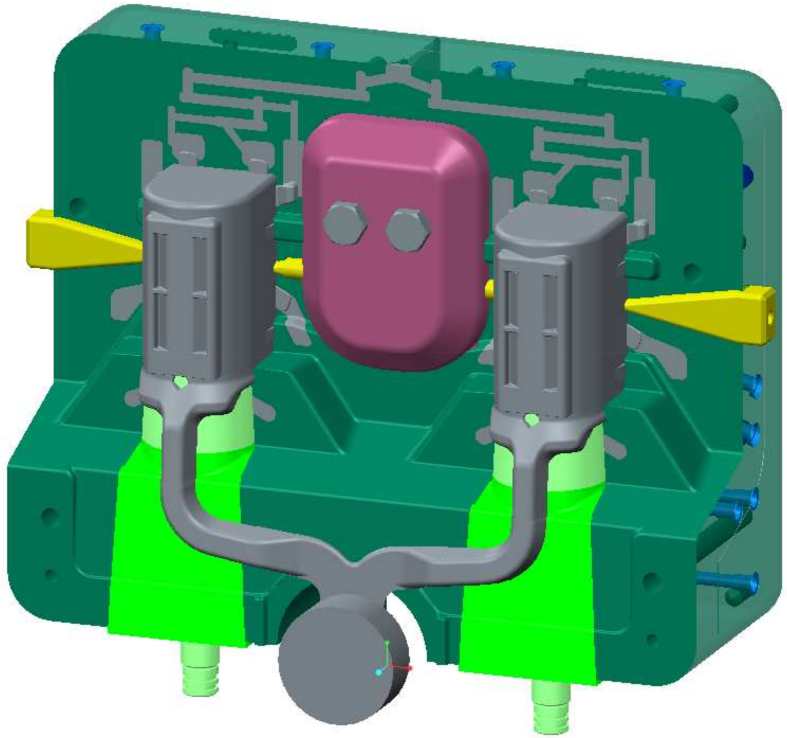
The real case

- ***2 cavities die with gate positioned over sliders***

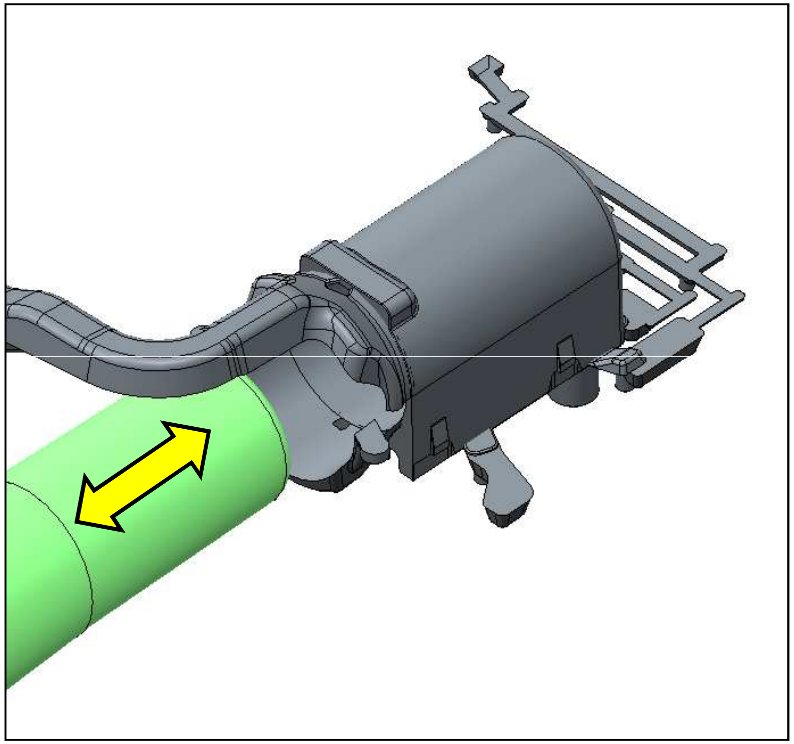


The real case

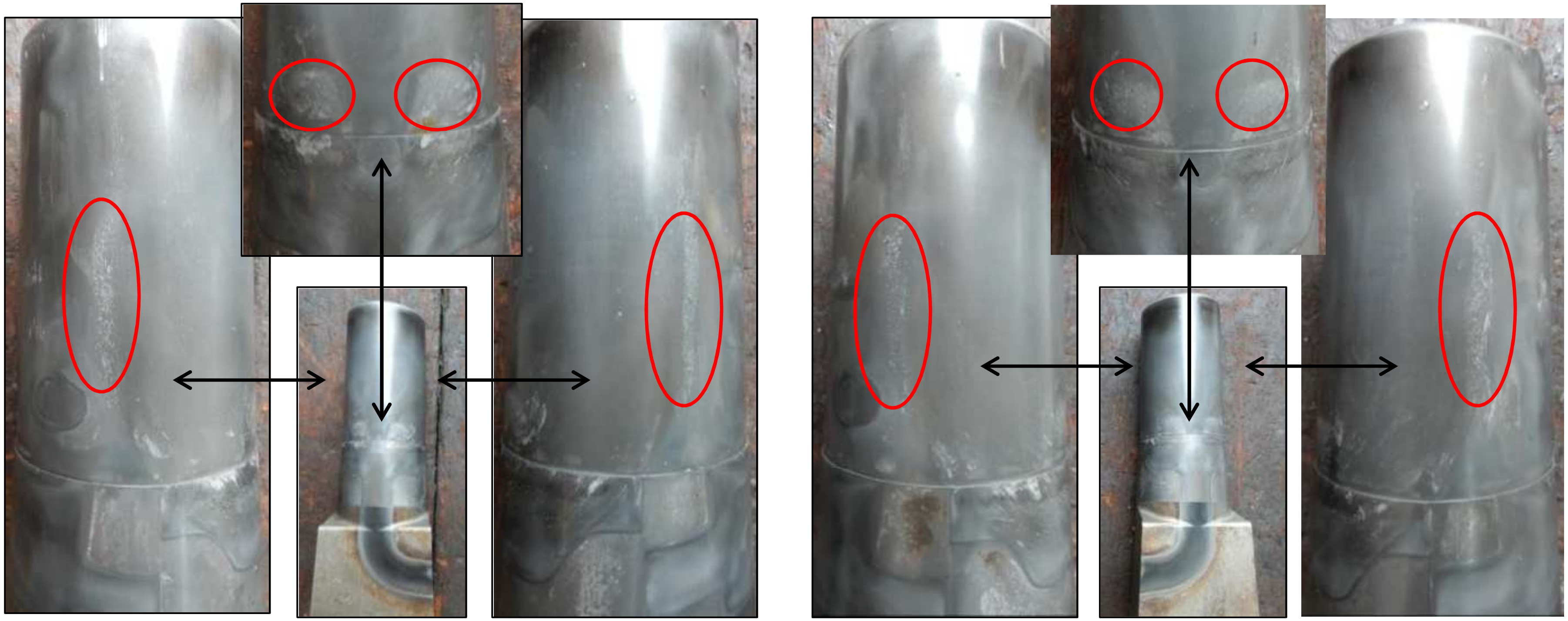
Sliders inserts have been made of different steel (all type 1.2343 / H13) :

- ***Böhler W300 Isodisk (original 2x)***
- ***Böhler W400 VMR (spare 1x)***
- ***Hitachi DAC-MAGIC (spare 1x)***

+ Hardening 46-48 HRc
+ Nitrided 0.05 mm deep
+ Coated with PVD TiAlN 3400 HV 0.5-5µm



Situation after 7.500 shots



Situation after 7.500 shots

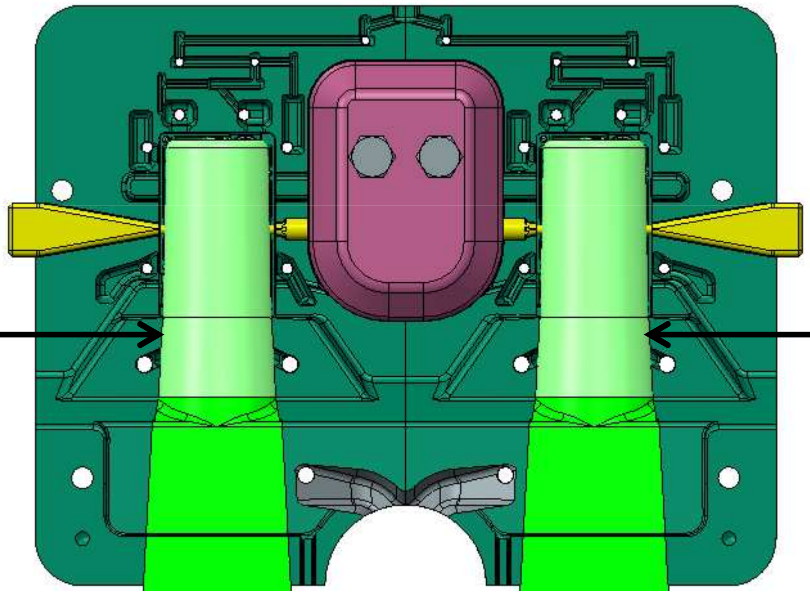
VIEW FROM OUTER SIDE SLIDER LEFT

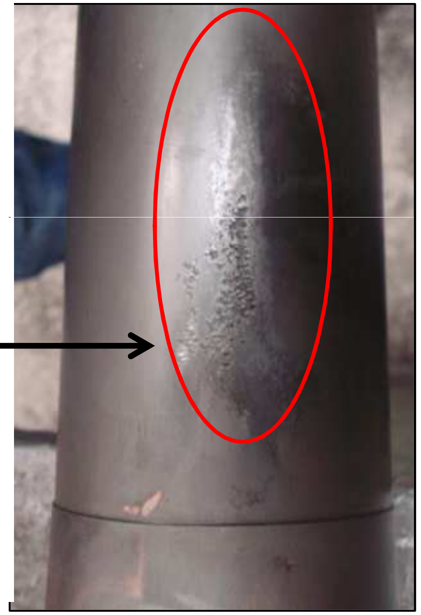
VIEW FROM TOP SIDE SLIDER LEFT

Situation after 20.000 shots

VIEW FROM OUTER SIDE SLIDER LEFT

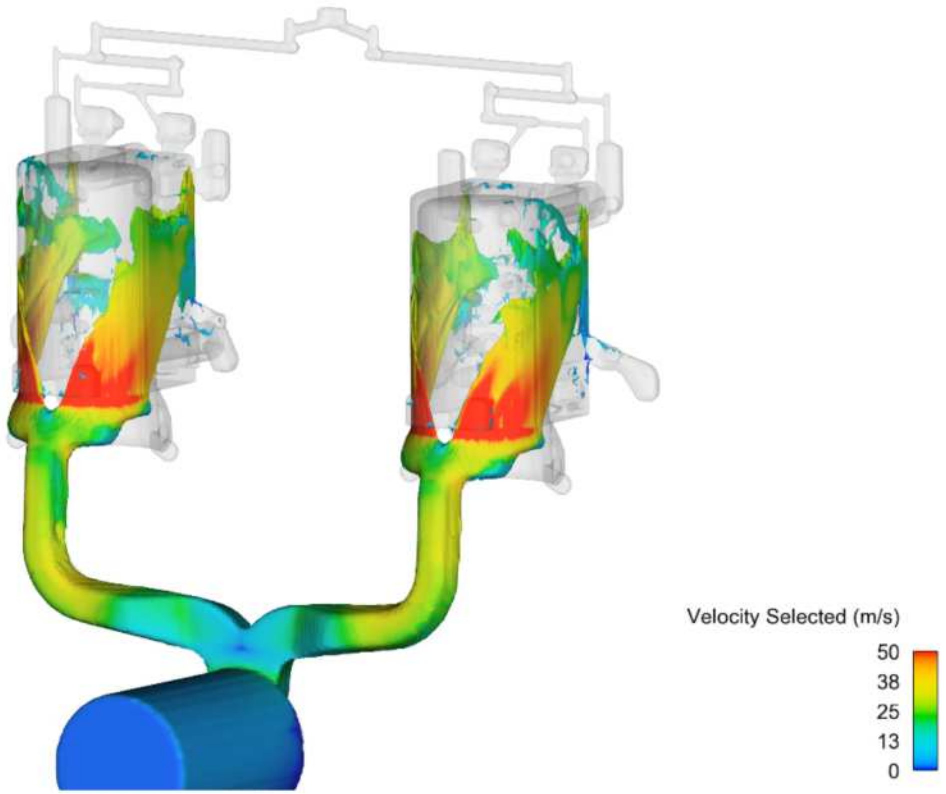
VIEW FROM OUTER SIDE SLIDER RIGHT





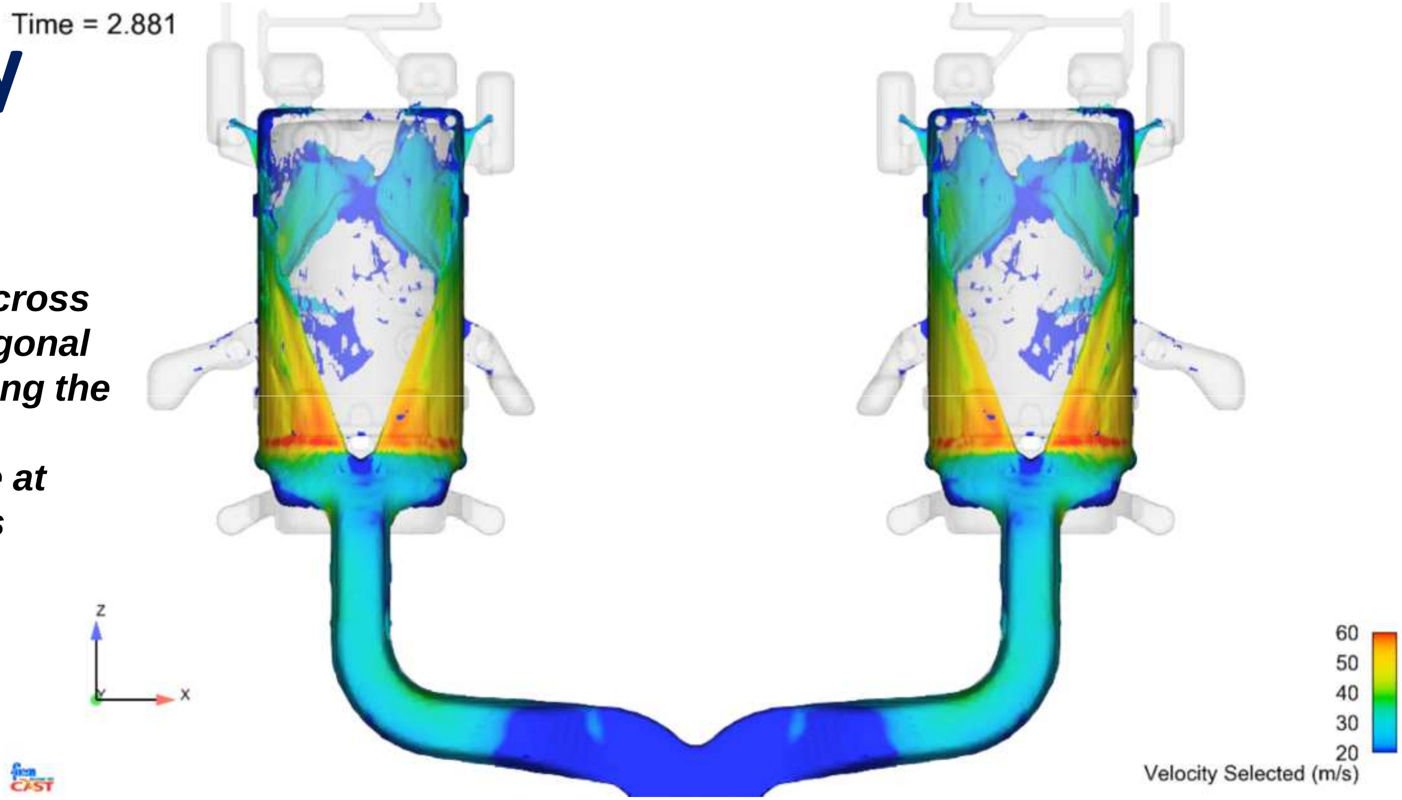
Simulation

- *Cell size on cavity (conform to open volume) X x Y x Z = 0.6 x 0.6 x 1 mm*
- *Simulation mirrored on Y-Z plane*
- *Total cells count 10.830.560*
- *Active models: Adiabatic gas regions, Solidification, Cav. Potential and Passive model*
- *Running parallel code on 12 processors*
- *Calculation time 17h on*



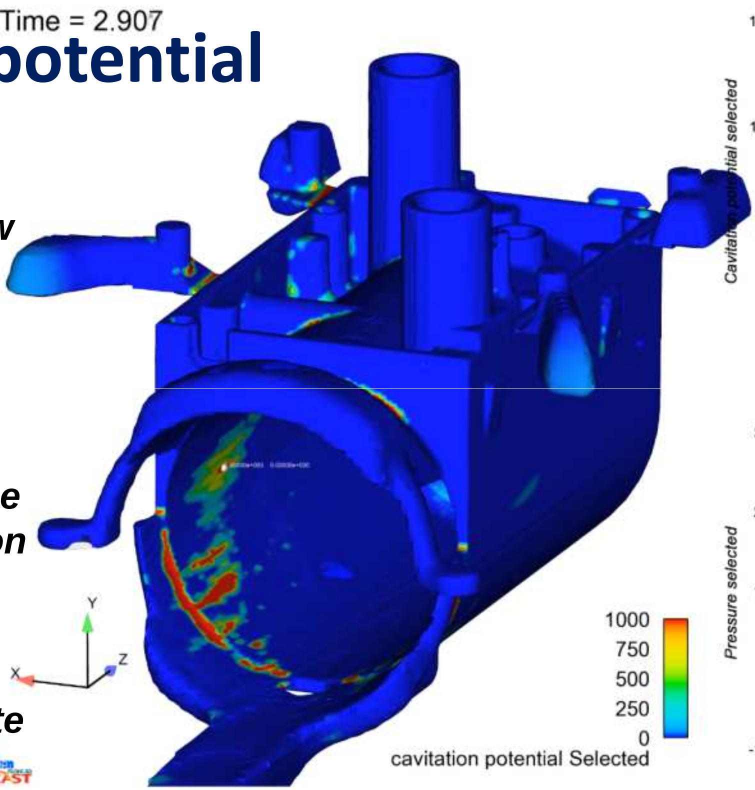
Velocity

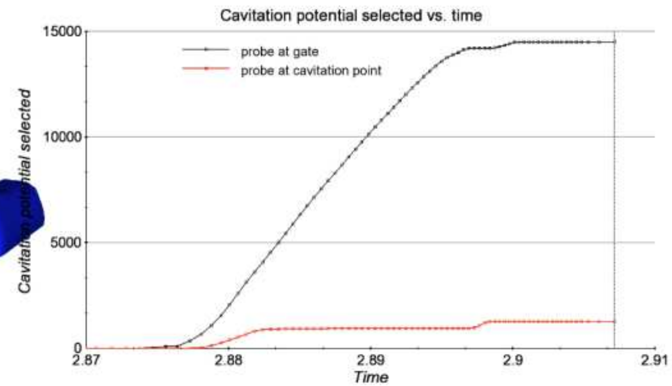
- ***The flow edges cross the cavity in diagonal direction wrapping the sliders***
- ***Speed 2^{nd} phase at gate up to 60m/s***

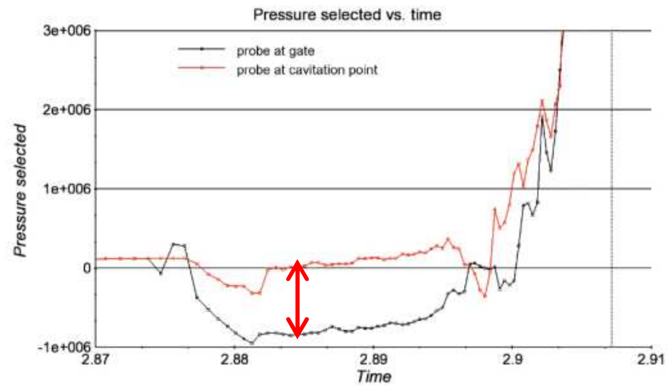


Cavitation potential

- ***The cavitation potential result show higher values at the gate***
- ***Here the bubbles nucleate due to pressure drop***
- ***But they will collapse later on the cavitation zone pressure get back. The gap of pressure between gate and here is quite high***

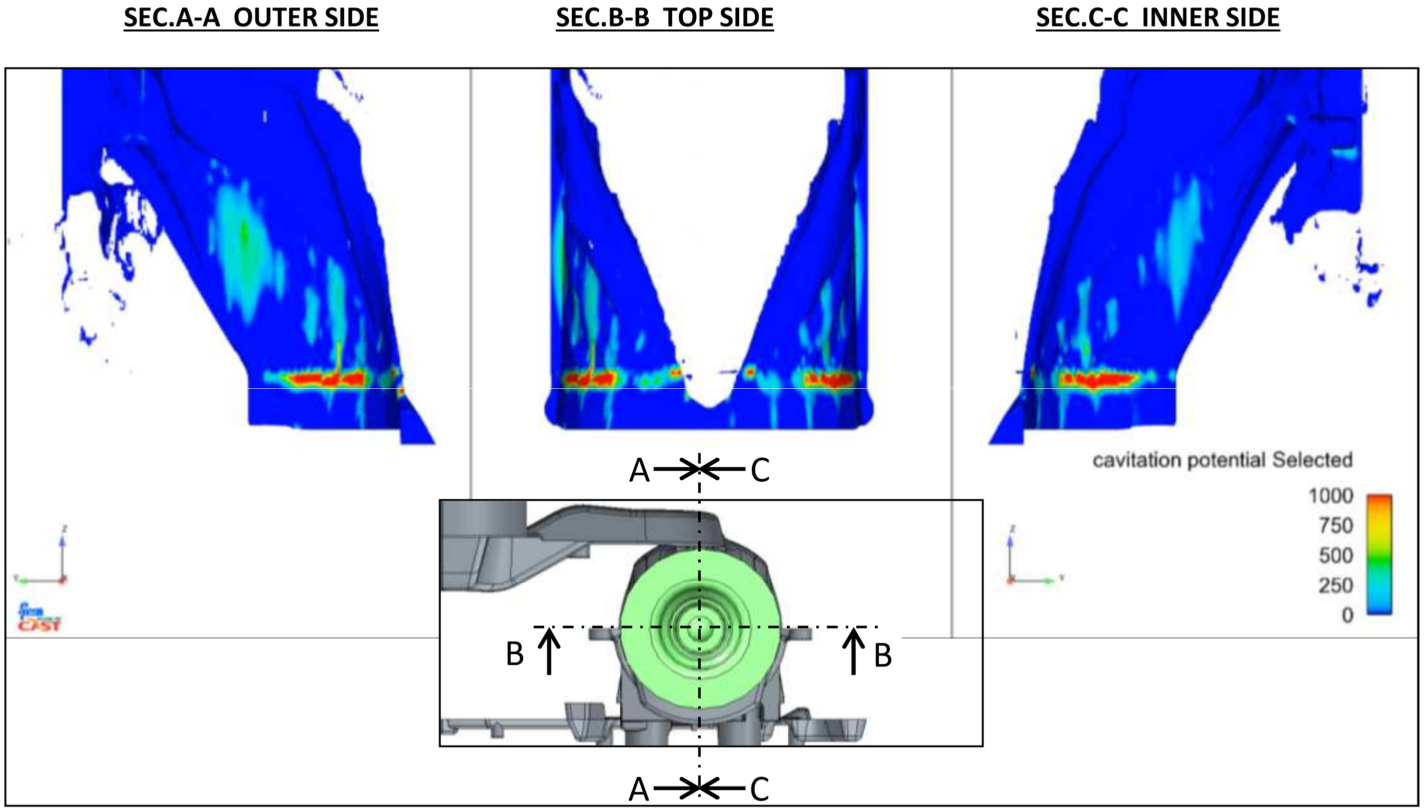






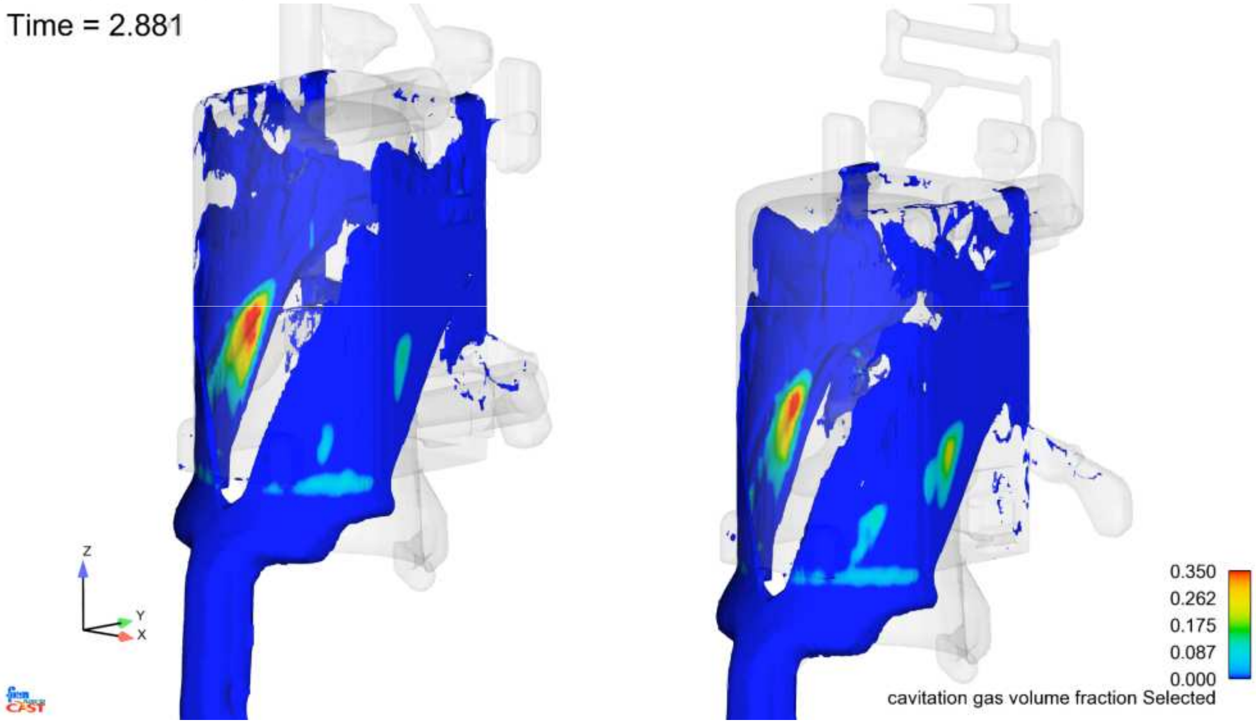
Cavitation potential

- ***This result doesn't show the cavitation zones***



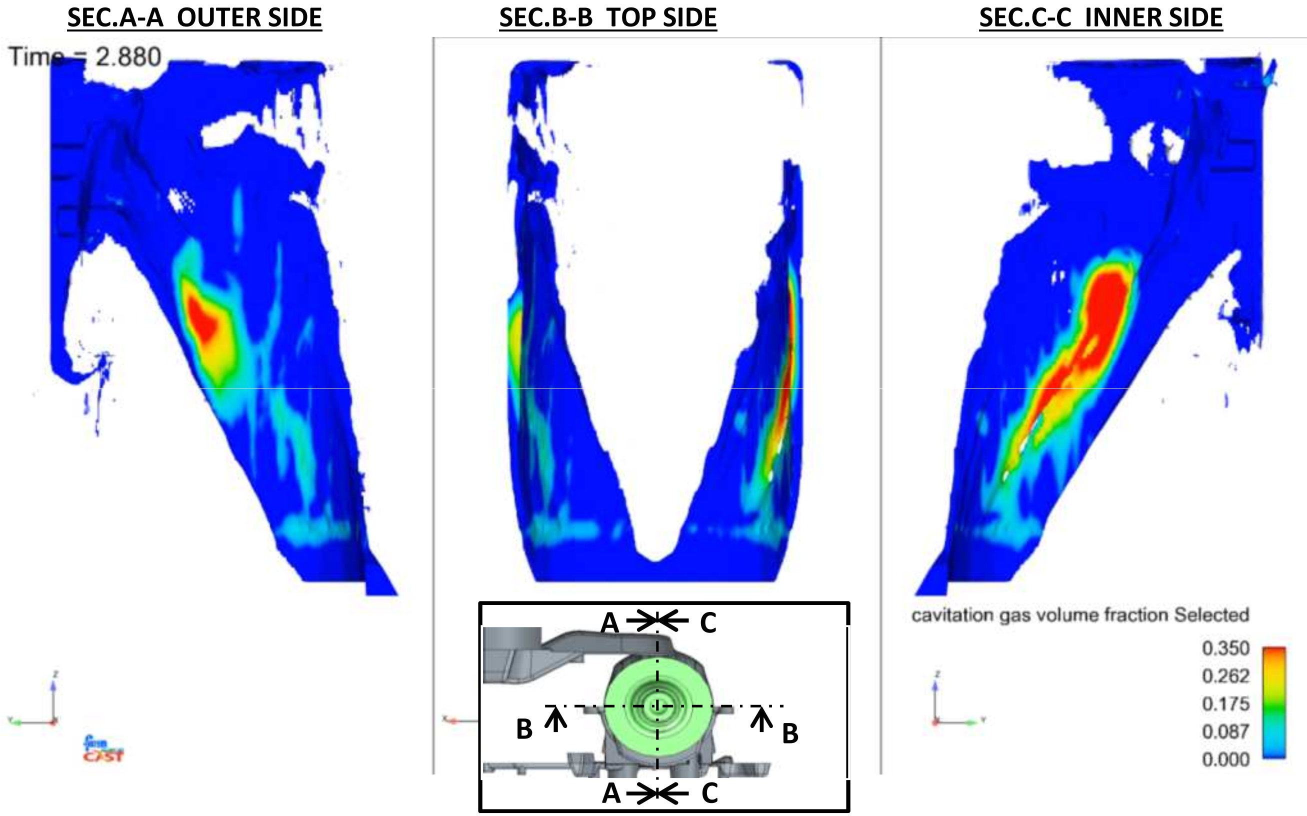
Cavitation passive model

- ***This result shows where the volume fraction of cavitation bubbles is bigger***



Cavitation passive model

- ***Bubbles volume formed at the gate and behind it will collapse suddenly after the red zone, where the volume disappears suddenly***

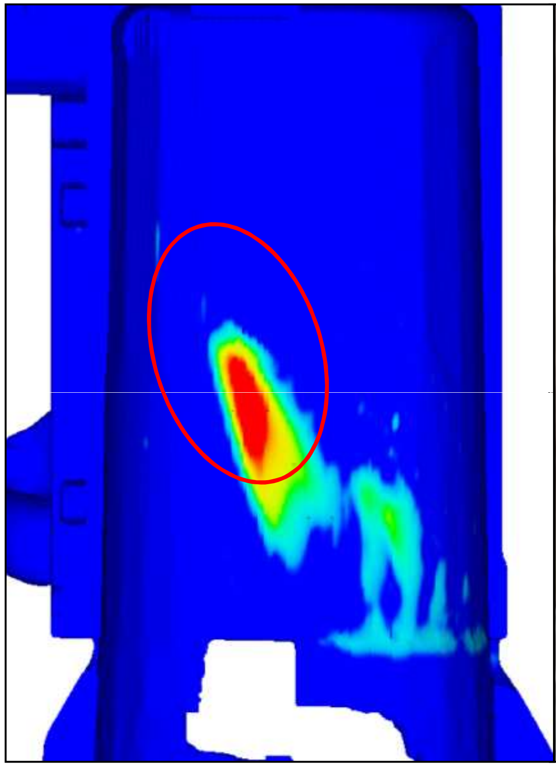


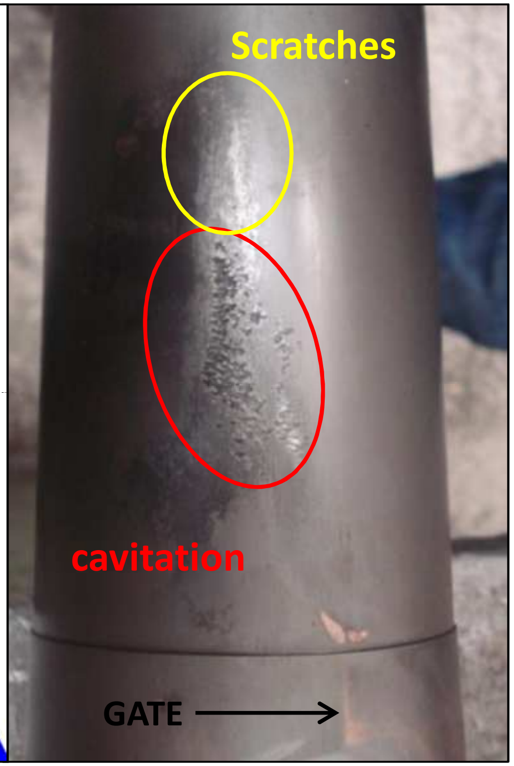
Cavitation passive model

- ***The position of pitting caused by cavitation is close to the zone marked in red, but moved a little bit forward in direction of the flow, where bubbles collapse***

➢ ***This result has a good correlation with the reality***

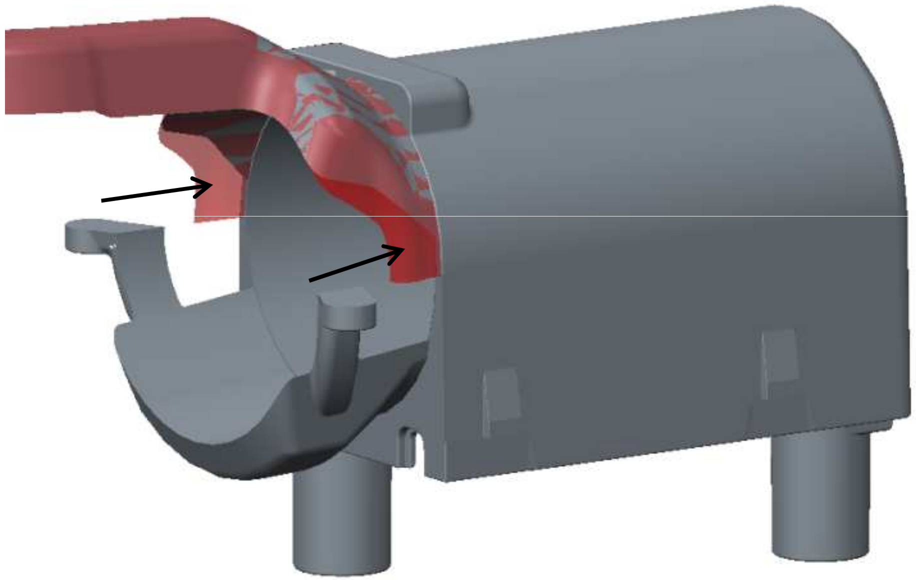
- ***In reality we can see also some scratches, but they are formed when slider is pulled back***





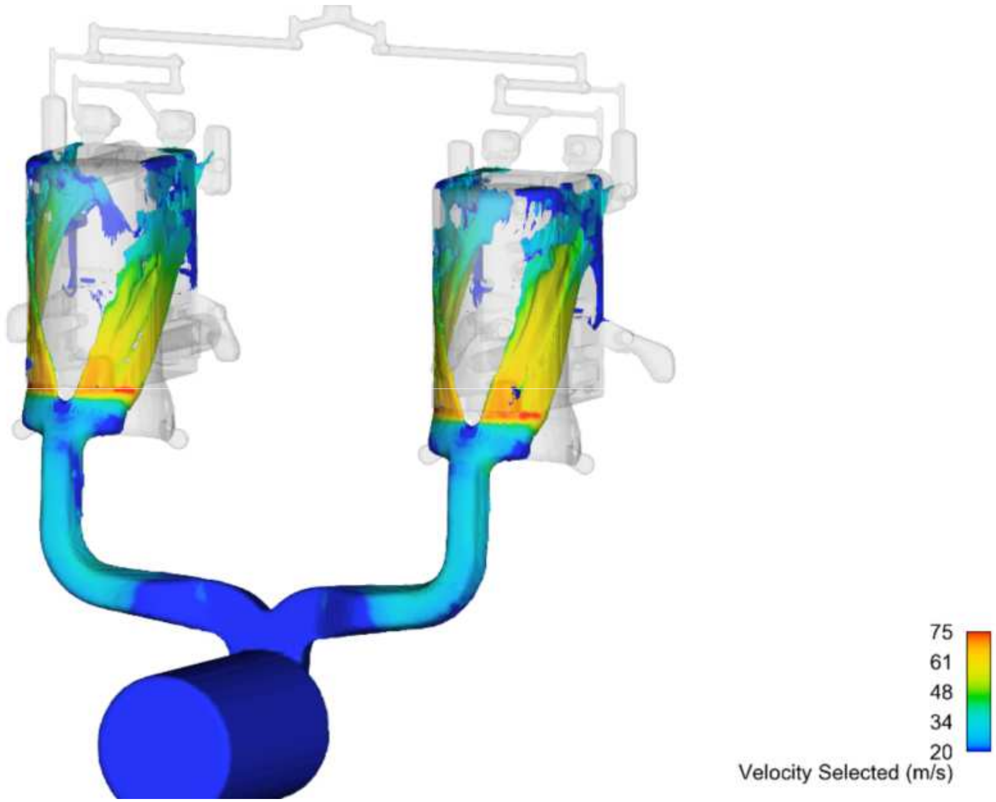
Gate design change

- ***The gates have been shortened by welding on the die the terminal of the "wings" on both sides***
- ***This geometry was made initially to increase the speed at gates thus improving the cast quality***
- ***… but then we recognized that also cavitation erosion was reduced, even if speed was increased***



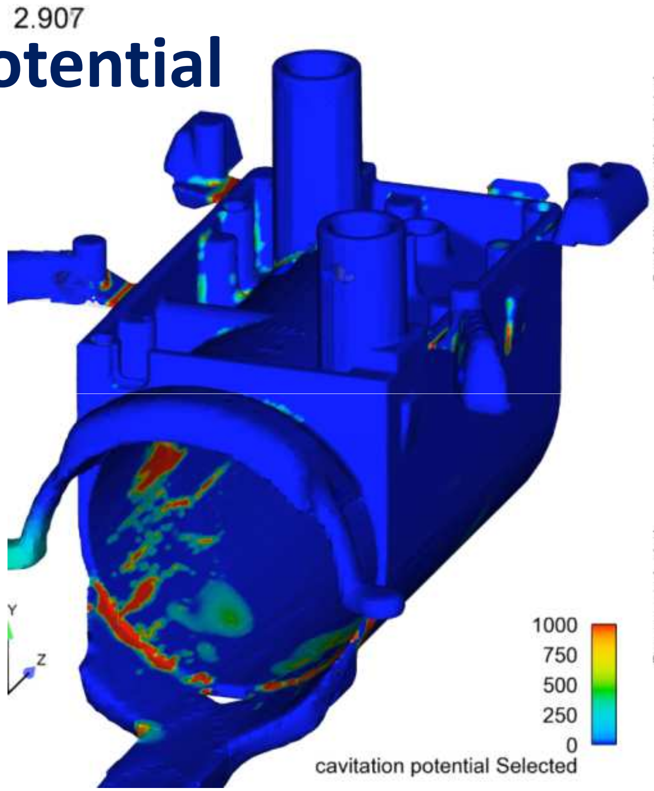
New simulation

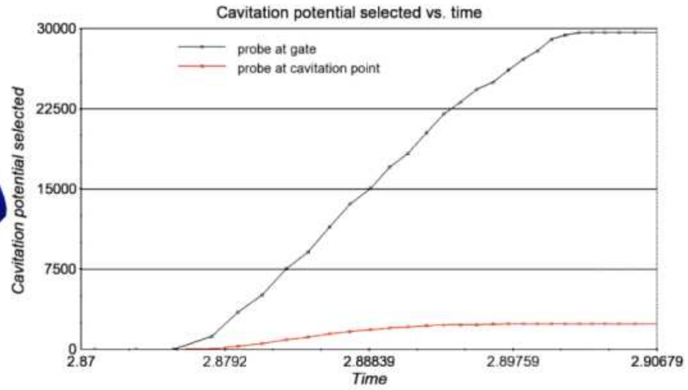
- ***Same parameters as first simulation***
- ***Speed 2nd phase at gate up to 75m/s***
- ***The direction of the flow from the gate is more longitudinal and there is less wrapping on the sliders***

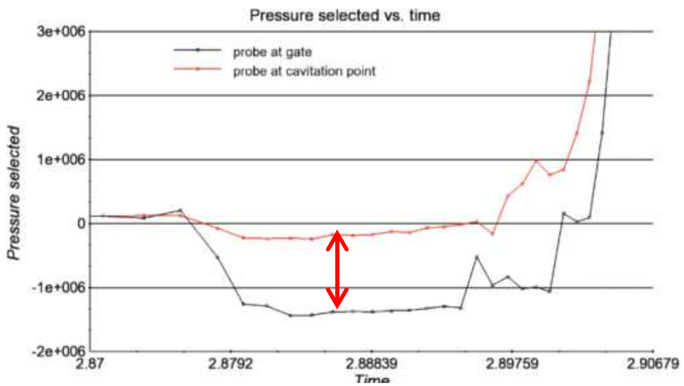


Cavitation potential

- ***After the change, due to higher velocity at the gates, here the pressure drop is even bigger and causes higher values of cavitation potential***
- ***But we can see also that the pressure gap between gate and cavitation zone is minor***



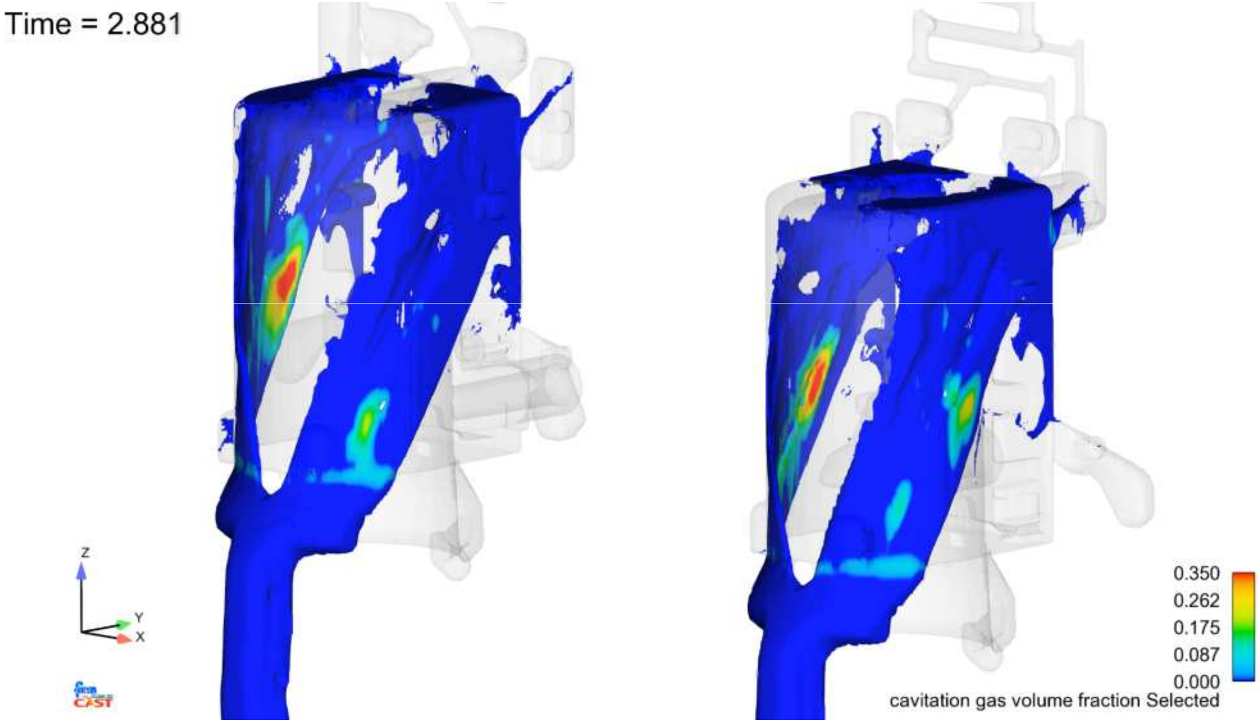




Cavitation passive model

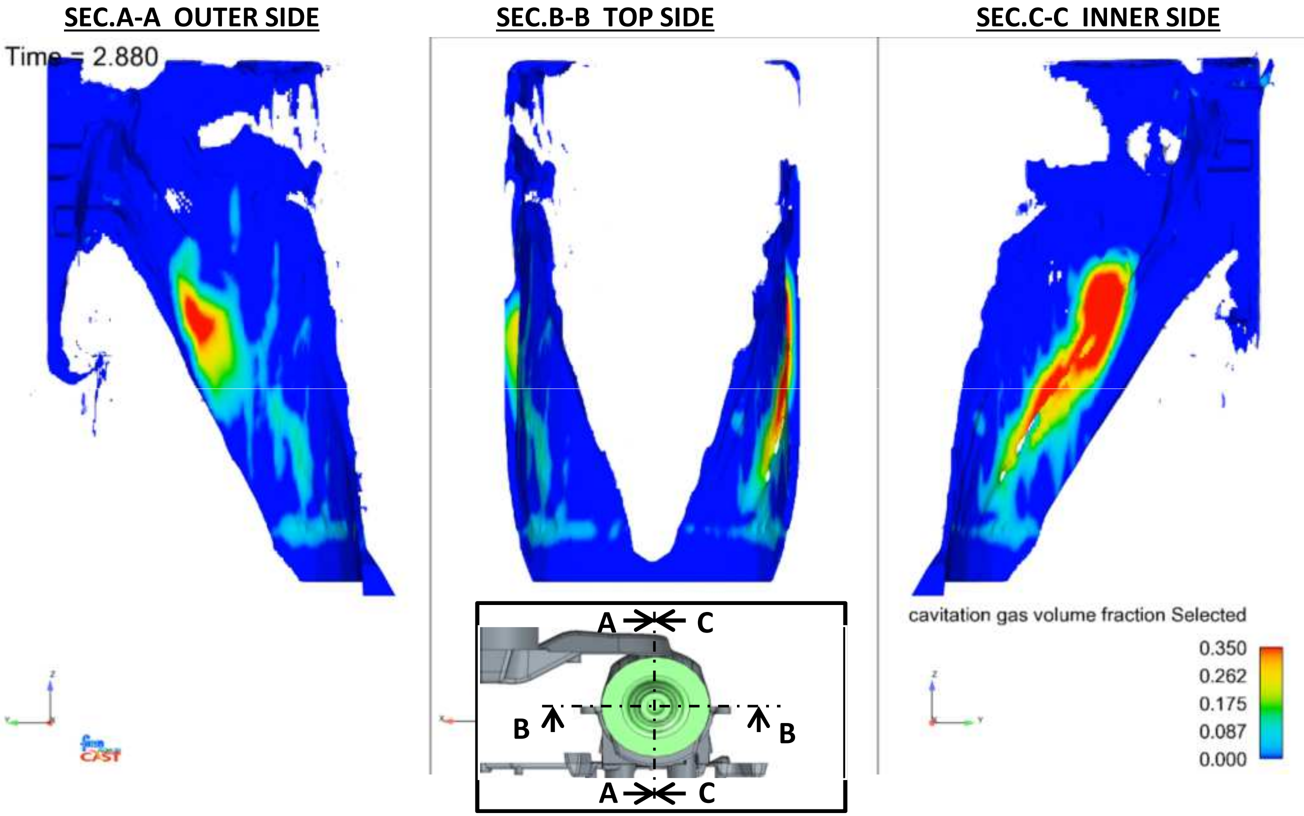
- ***Also cavitation gas volume fraction result gives higher values***

- ***With the change the red zone has moved a little bit forward, farer from gates***



Cavitation passive model

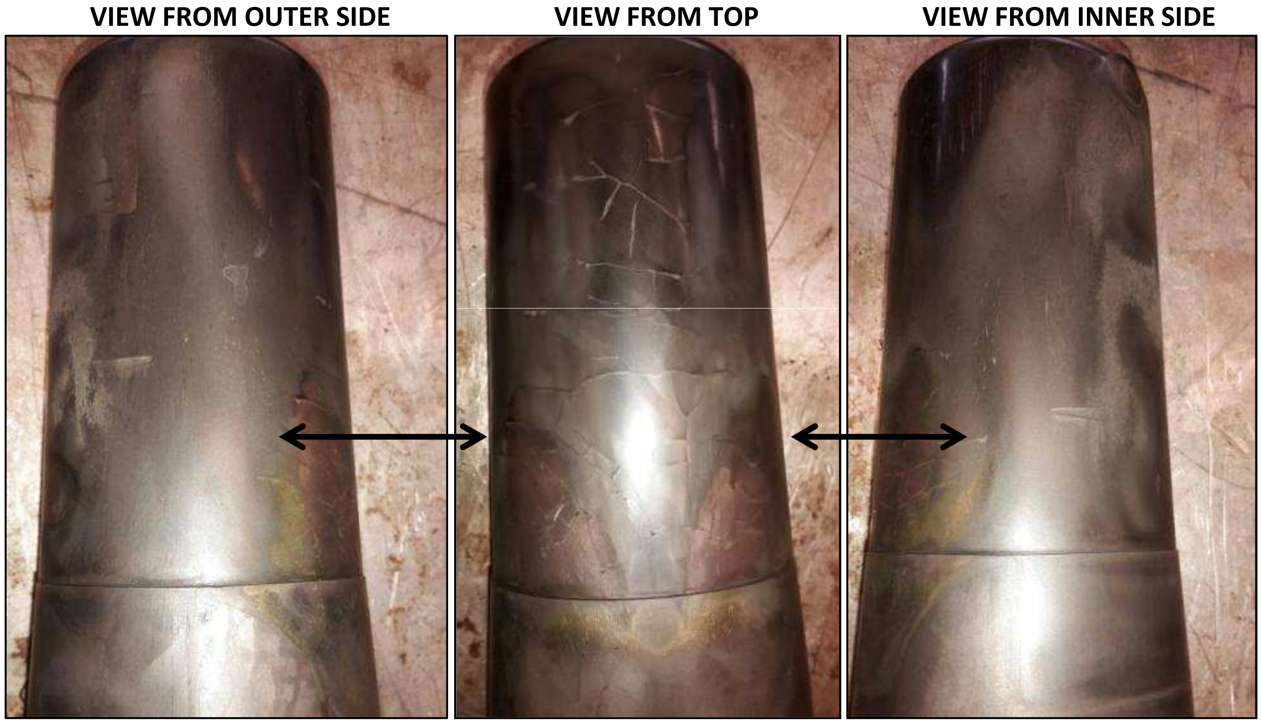
- *The red zones are wider and they stand longer during the filling*
- *Looking to these results it seems that the change of gate geometry leads to an increment of cavitation erosion of the die but in practice…*



Situation after <u>100.000</u> shots (with new gate design)

…Looking to the pictures of the sliders at the end of their lifetime it it's obvious that the cause of their end is not cavitation erosion (like before) but heat cracks

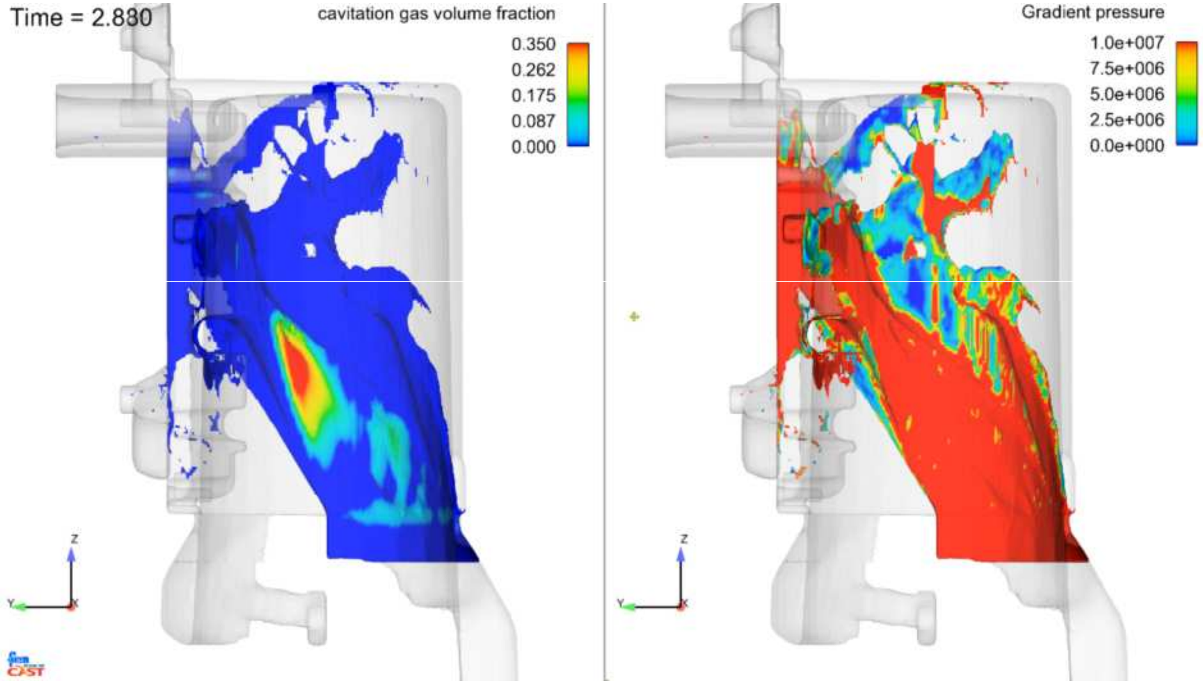
Then the cavitation erosion is almost disappeared even with higher velocity at gate



Gas volume fraction vs Pressure waves (original gate)

- ***We feel that the cavitation erosion depends not only by the volume of bubbles but also by how fast the bubbles collapse***

- ***Looking at the gas volume fraction and gradient of pressure together we can have the feeling if and where the erosion should take place***



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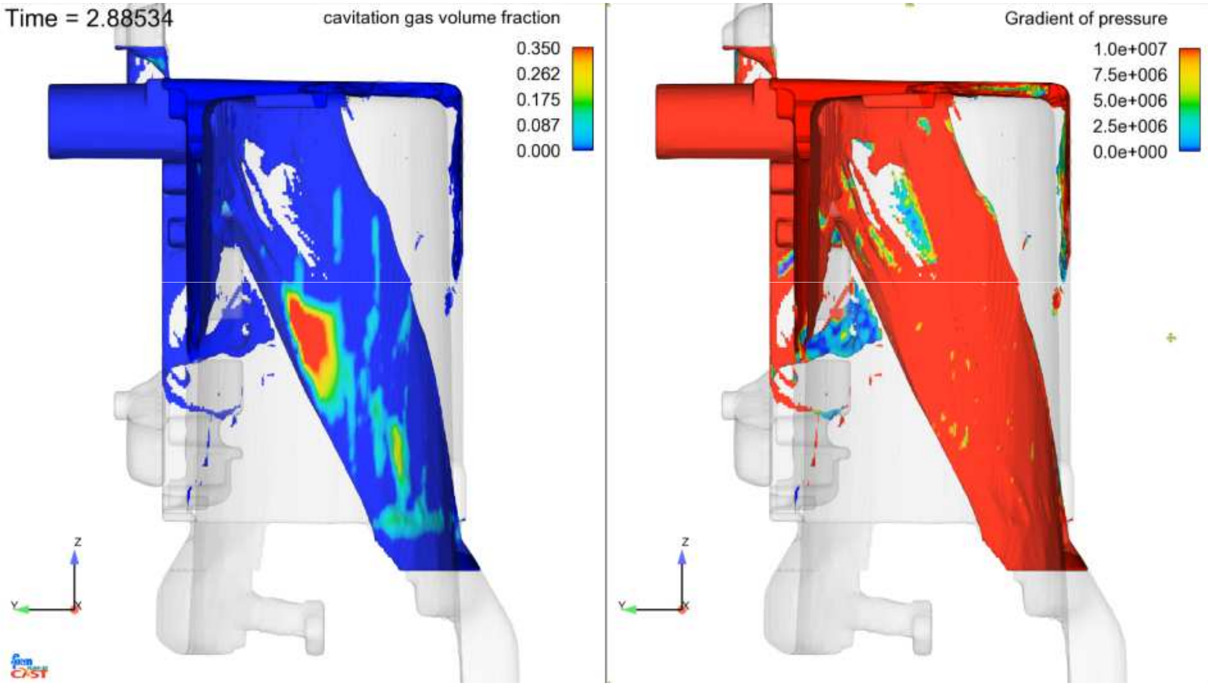
Gas volume fraction vs Pressure waves (new gate)

- ***By this way can understand why the new design of gate is better***

- ***the flow is more compact and the pressure more stable while crossing the cavity***



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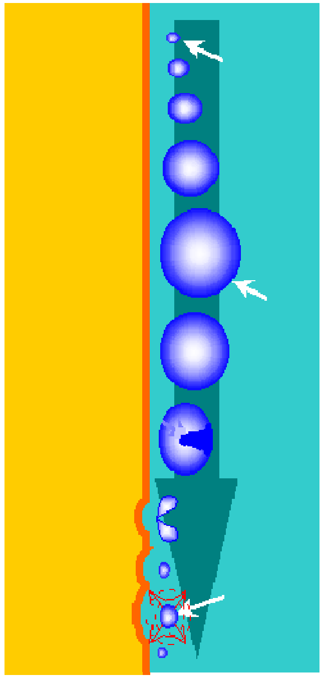
Purpose for new Cavitation Erosion model



Cavitation Potential model

Predicts zones where bubbles nucleate

Cavitation Volume Fraction (Passive) model

Predicts the volume evolution of these bubbles

Cavitation Erosion model

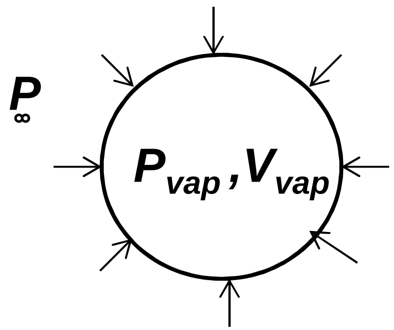
We need a model that predicts where damages will occur and their amplitude

Cavitation erosion model (by Fortes Patella [1])

Cavitation Potential Power

The instantaneous potential power of the cavitating flow can be derived from a consideration of the macroscopic cavity structure. It is defined by:

$$P_{pot} = \Delta p\left(\frac{dV_{vap}}{dt}\right)$$



Where $\Delta p = P_\infty - P_{vap}$ ***,***
P_∞ ***is the surrounding pressure,***
P_{vap} ***is the vapor pressure***
V_{vap} ***is the vapor volume at given time t***

[1] Fortes-Patella, R., Reboud, J.L. and Briancon-Marjollet, L. 2004; "A phenomenological and numerical model for scaling the flow agressiveness in cavitation erosion", EROCAV workshop, Val de Reuil

Phisical energy transfer process

Cavitation Potential Power

Hydrodynamic characteristics of the main flow
Distance between collapse center and material surface

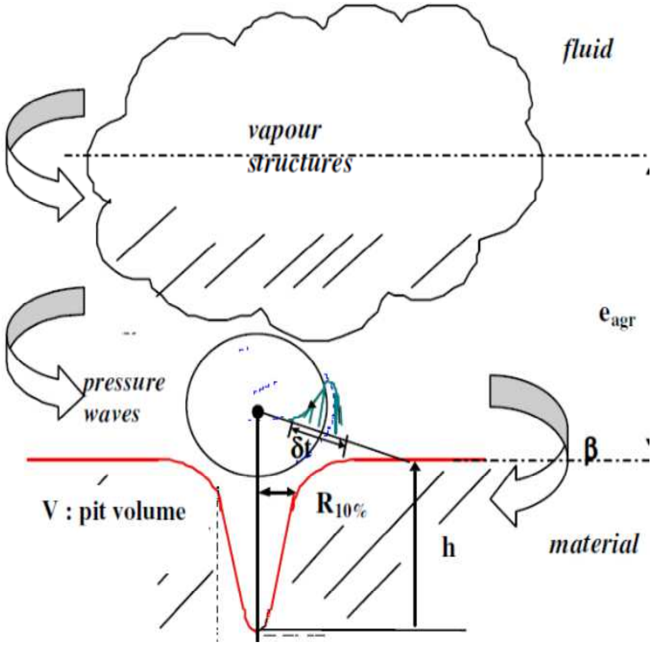
Flow aggressiveness Potential Power

Change in the surrounding pressure
Air content in the flow

Pressure wave Power

Characteristics of the material

Volume Damage rate



Conclusions

- ***Both Cavitation Potential model and Cavitation Passive model have been tested and gives useful indication about cavitation bubbles nucleation and evolution***
- ***In HPDC high volumes of cavitation bubbles may nucleate ad gates due to high acceleration and pressure drop of the flow at gate, but not necessary they lead to die erosion***
- ***A new model to predict Cavitation Erosion has been mentioned. It's based on the information given by the existing models but it considers also how fast the volume of bubbles collapse***

Thanks to

Brabant Alucast

XC ENGINEERING SRL
Numerical modeling services