

**Flow Measurement Institute
Conference 2017**



Study of the effects of geometrical features on flow patterns in multiphase flowmeters

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- Introduction – why this Research on Venturi flowmeters?
- Geometry1: 2D & 3D numerical results
 - Discussion on entrance length (100D vs 200D)
- Geometry2: 3D numerical results
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- Conclusion



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Why this Research on Venturi multiphase flowmeters?

- Venturi has several advantages:
 - Low cost
 - Simple operation
 - High accuracy velocity measurement when the flow mixture has uniform homogeneous properties



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However

- Venturi does not work well for multi-phase flow measurements



Multiphase flow meters can have an uncertainty on component flow rate of 20% or greater under field conditions.

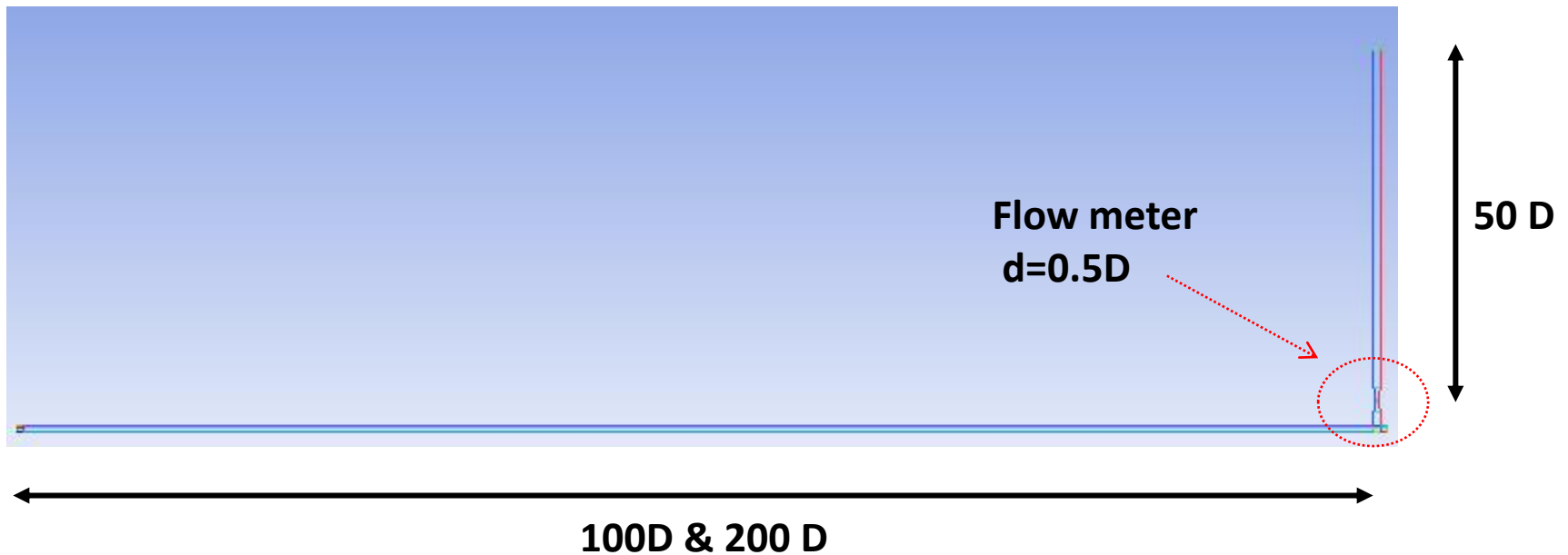
European project EMRP 'MultiFlowMet' started to generate experimental & numerical data to obtain better multiphase flowmeter data

- European Metrology Laboratories: NEL (UK), CMI (Czech Republic), PTB (Germany), VSL (Netherlands)
- Universities: Leeds, Cranfield
- Industrial partners...

Started (officially) the 1st June 2014, for 36 months

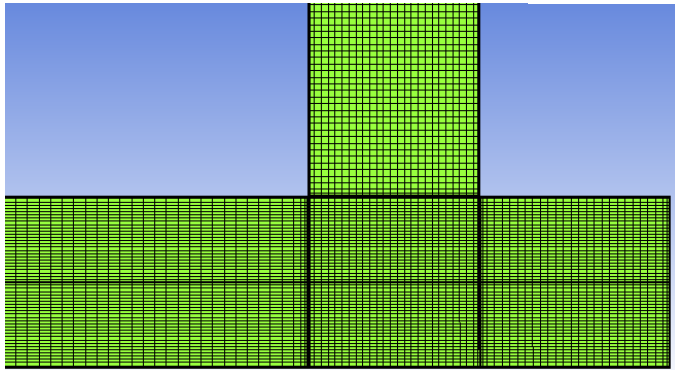
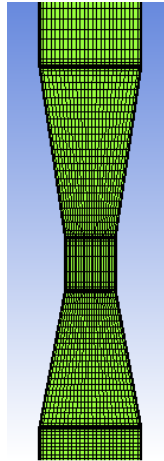
Geometry 1

$D=54.8\text{mm}$ (2in)

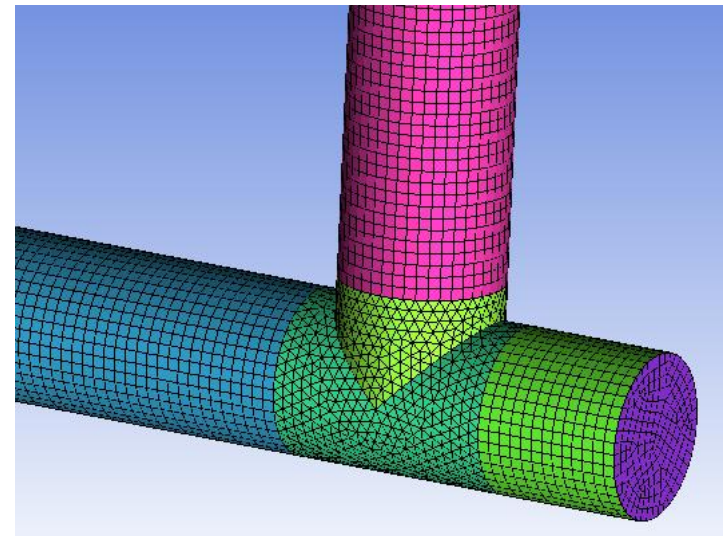
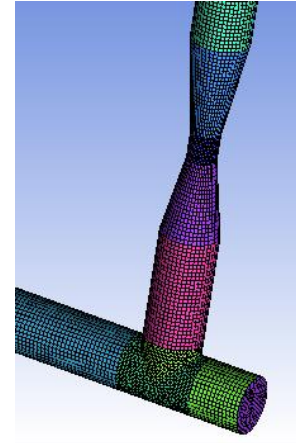


Meshes (Geometry 1)

- 2D model (200D)
- 200,000 cells

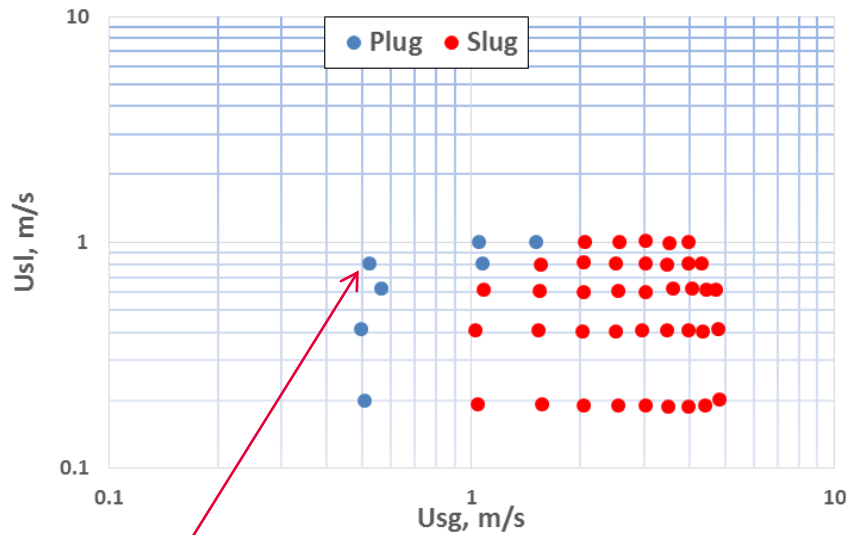


- 3D model
- 427,000 cells (100D)
- 700,000 cells (200D)



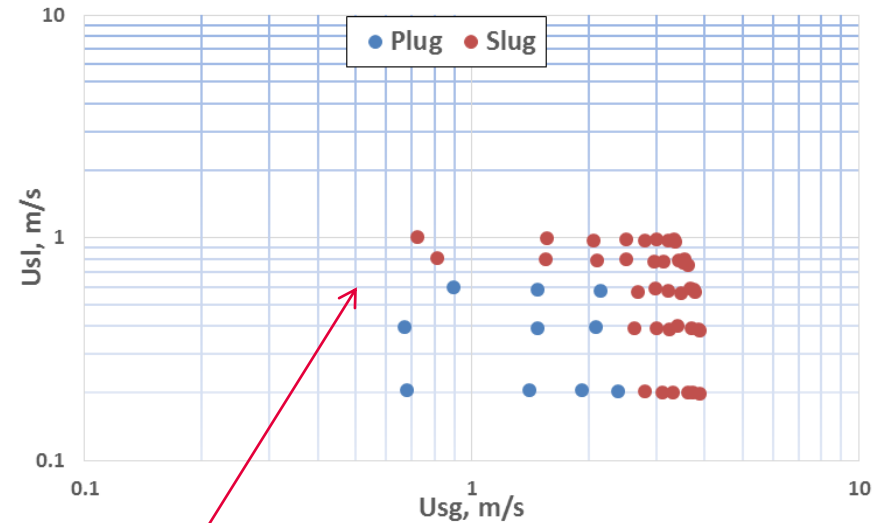
Geometry 1 - flow regime maps - 100D & 200D models

Horizontal section (100D)



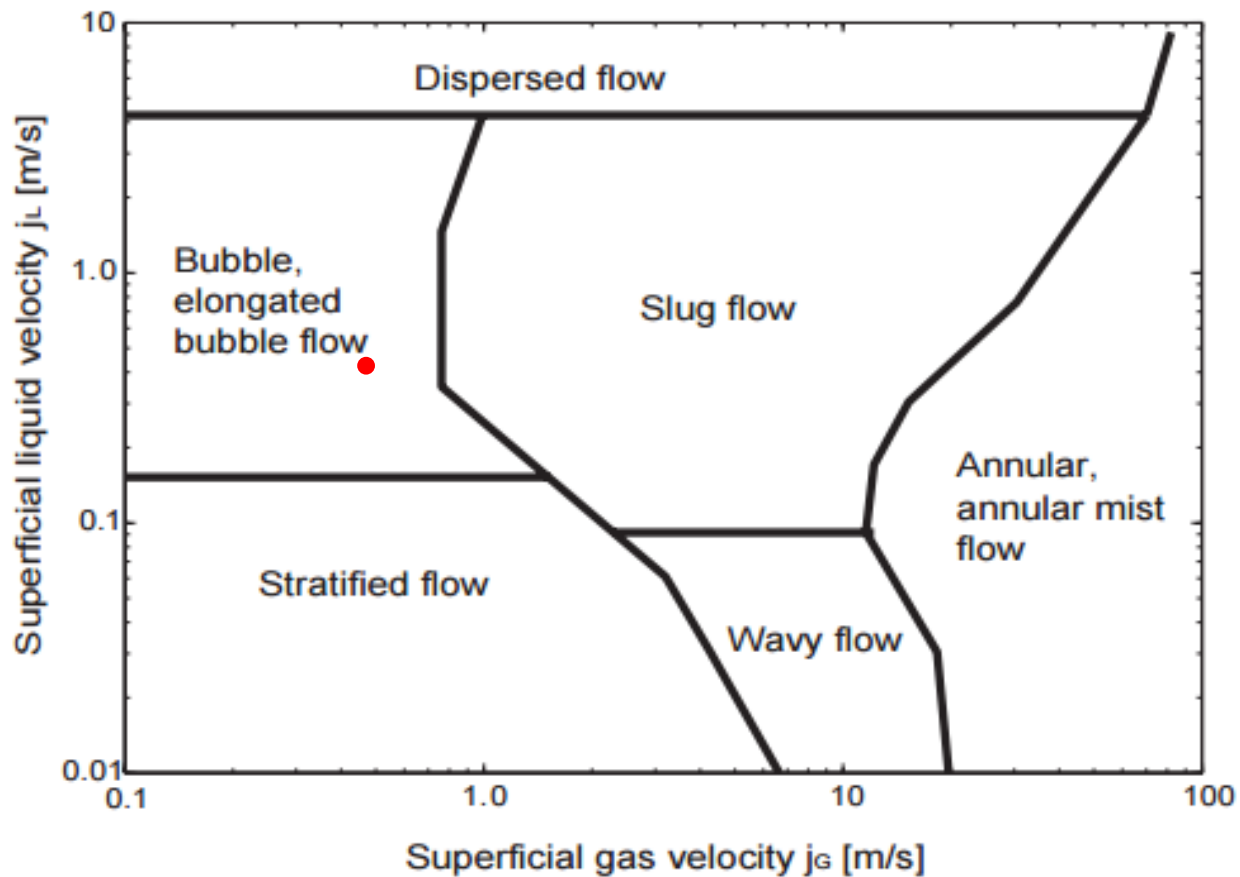
$U_{sg}=0.5\text{m/s}$,
 $U_{sl}= 0.6\text{m/s}$

Horizontal section (200D)



$U_{sg}=0.5\text{m/s}$,
 $U_{sl}= 0.6\text{m/s}$

Flow regime map (Madhane et al., 1974)

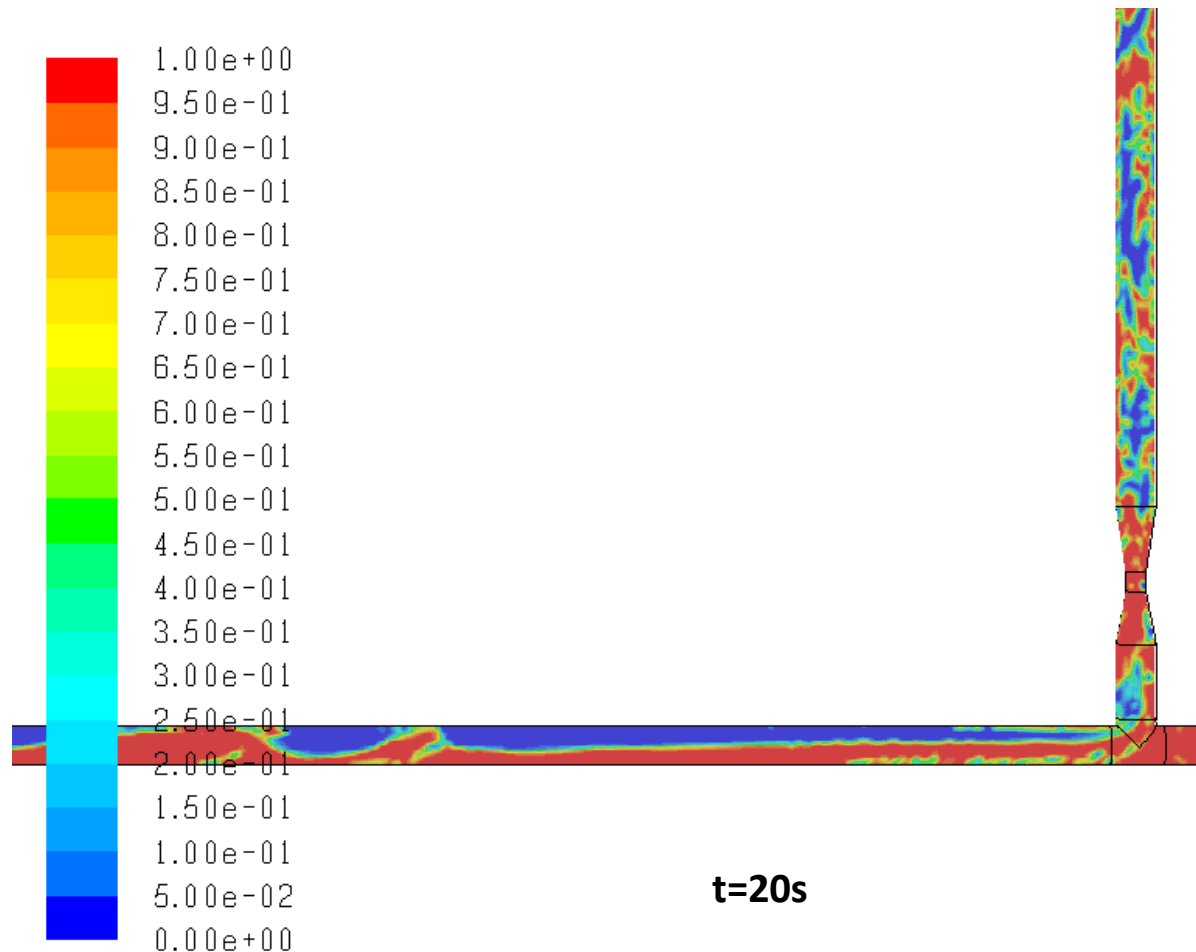




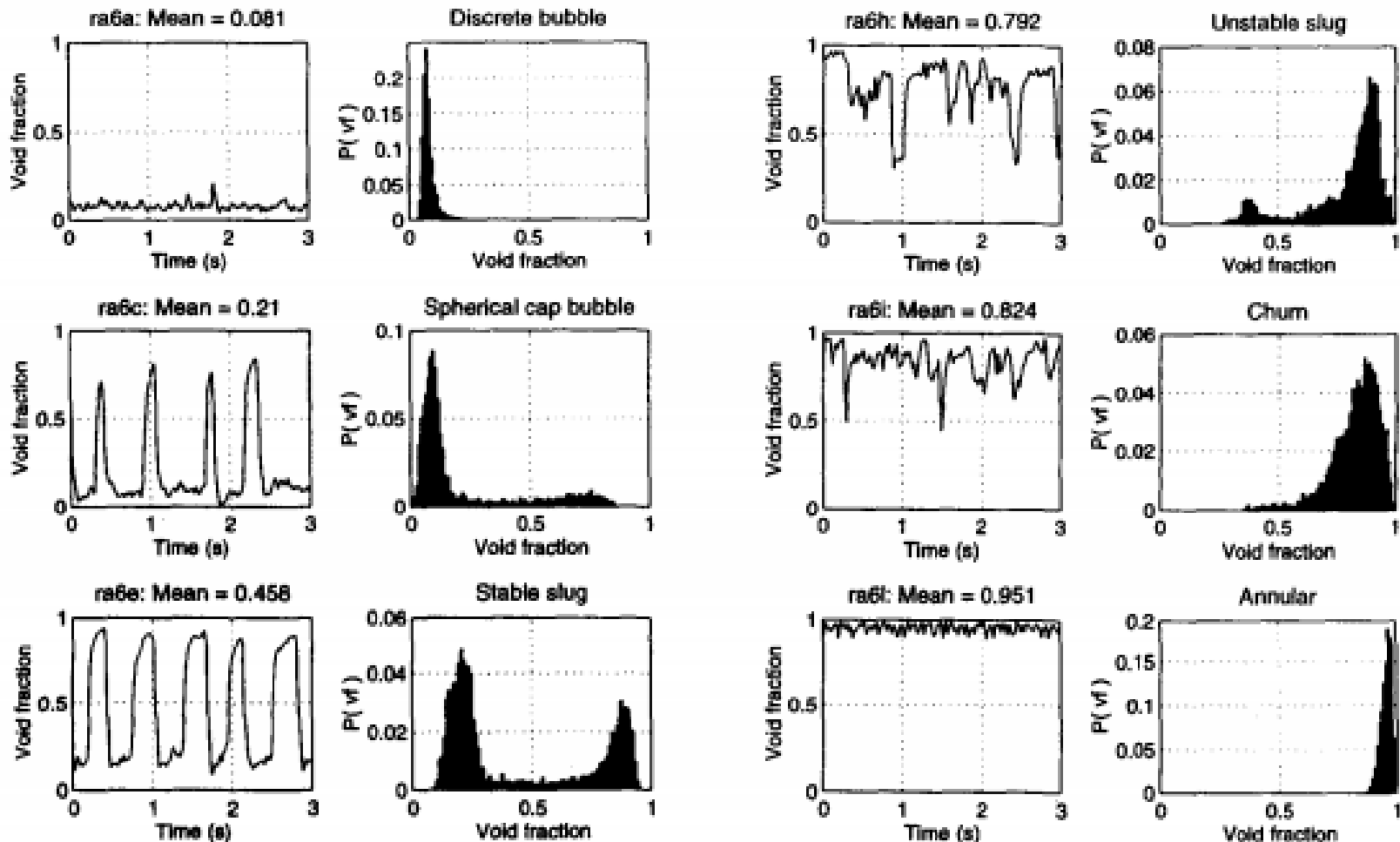
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3D model - 100D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$

- Air/water
- VOF model
- Kw-SST
- Transient



Flow regime identification (Costigan and Whalley, 1997)

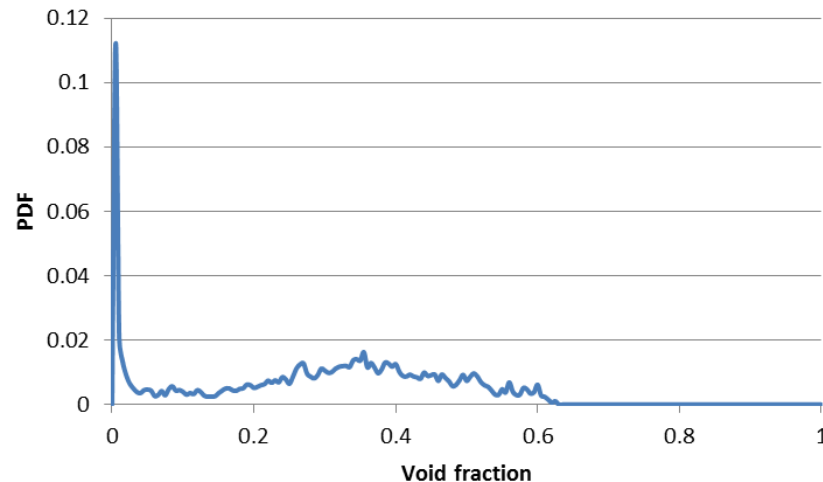




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PDF - 2D 200D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$

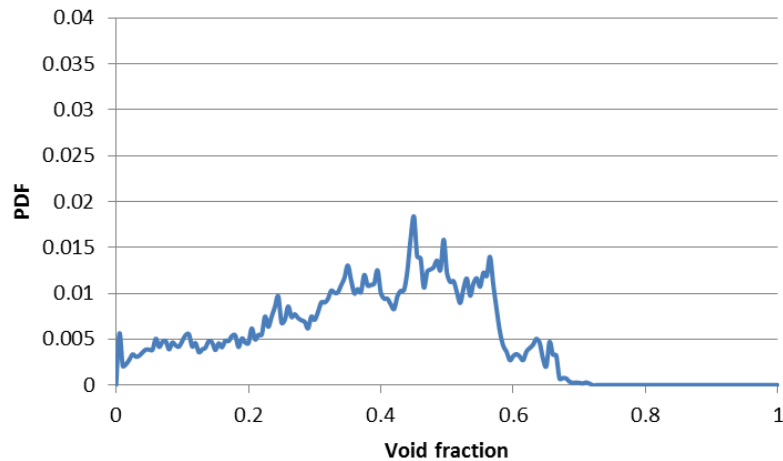
Horizontal section (200D)



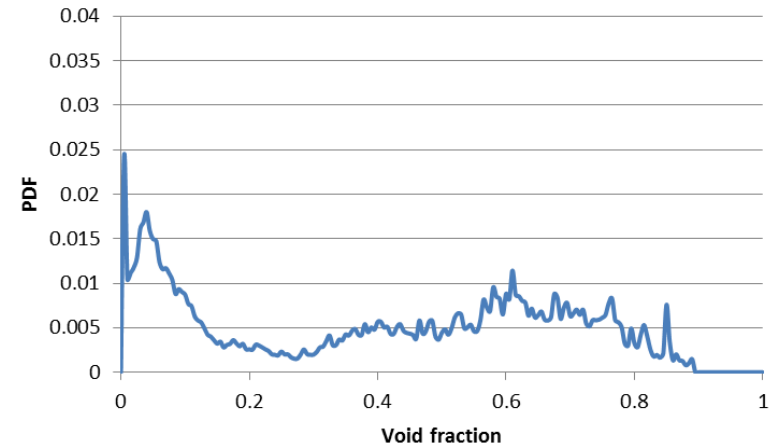
- ⇒ 100D entrance length-based results did not work (2D case)
- ⇒ 200D entrance length-based model predicts an elongated bubble flow regime

PDF - 3D - 100D & 200D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$

Horizontal section (100D)

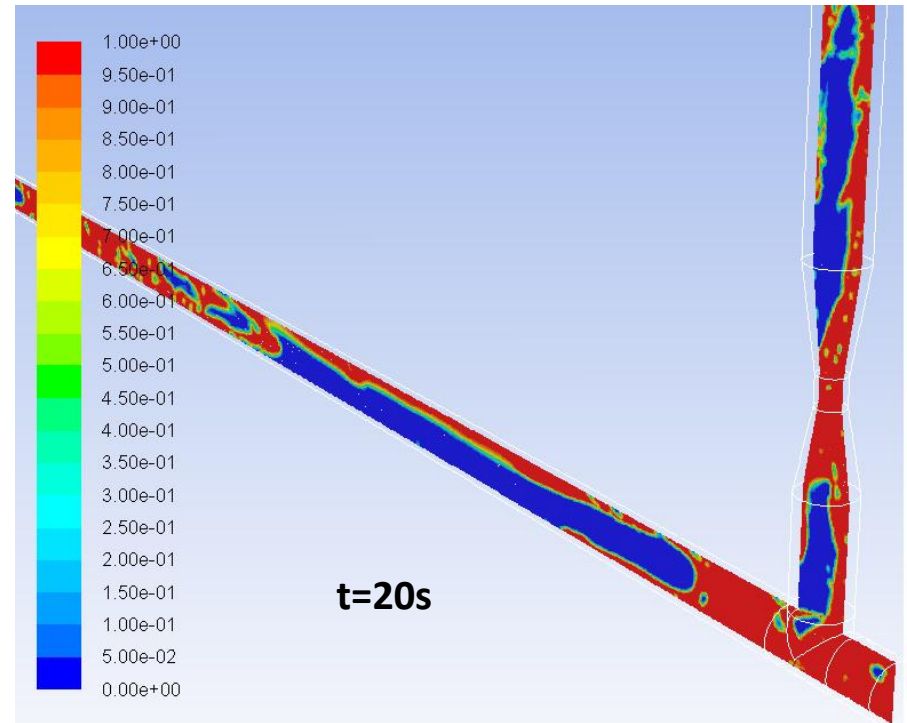
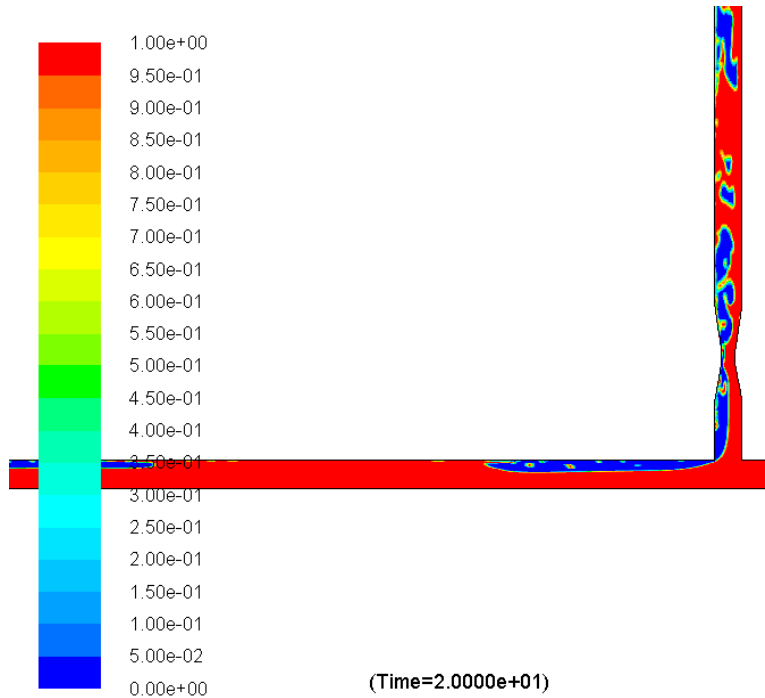


Horizontal section (200D)



- ⇒ 100D entrance length-based results seem un-reliable
- ⇒ 200D entrance length-based model works better

2D/3D models - 200D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$





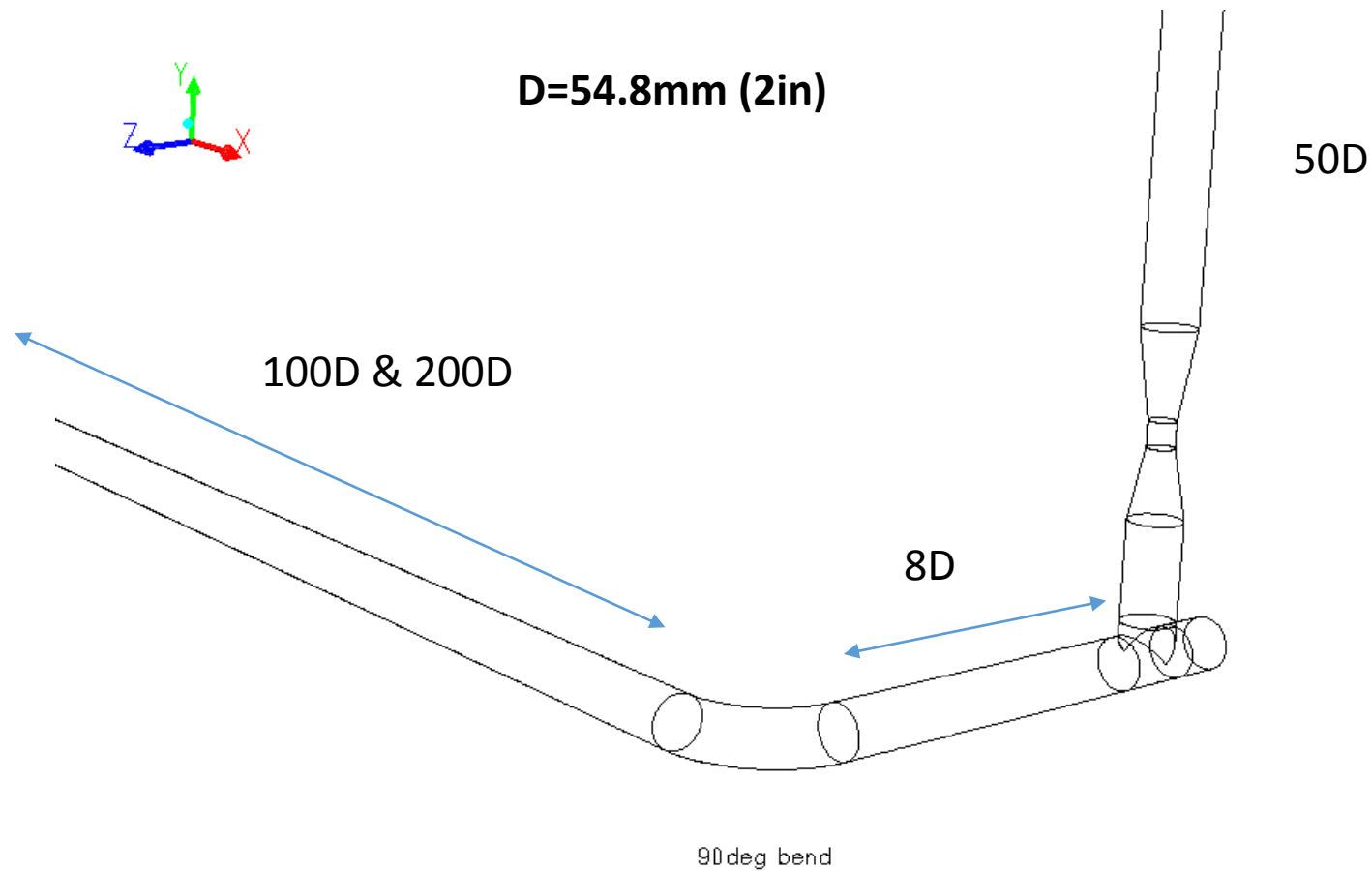
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Conclusion – Geometry 1 – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$

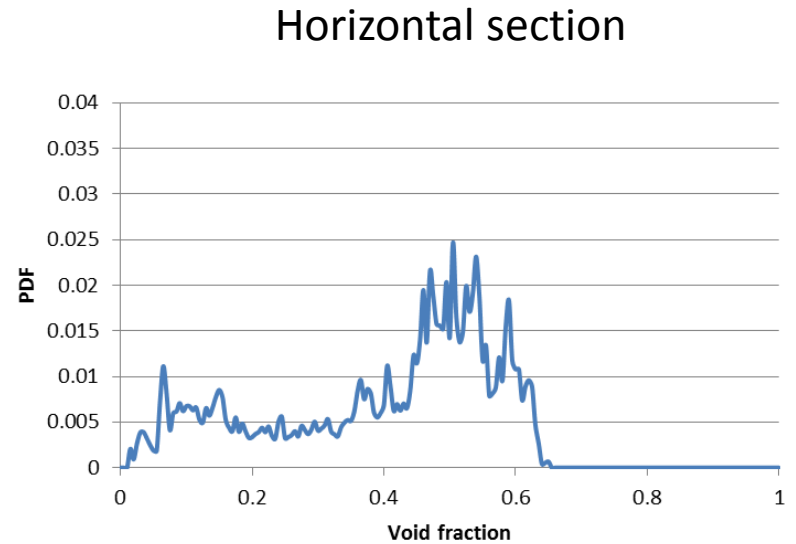
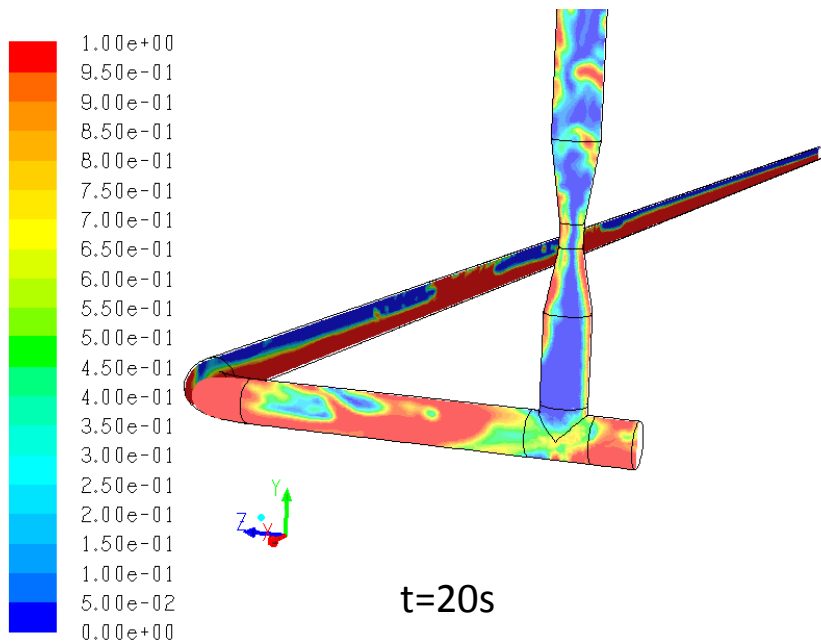
- 2D simulation not successful for 100D entrance length
- 2D simulation can predict correct flow pattern (200D)
- 3D simulation not reliable for 100D entrance length
- 3D simulation can predict correct flow pattern (200D)

- ⇒ **A 100D entrance length is too short to predict the correct flow regime**
- ⇒ **Further cases are required to conclude fully!**
- ⇒ **Conclusions valid only for the horizontal section**

Geometry 2



Geom 2 - 3D - 100D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$

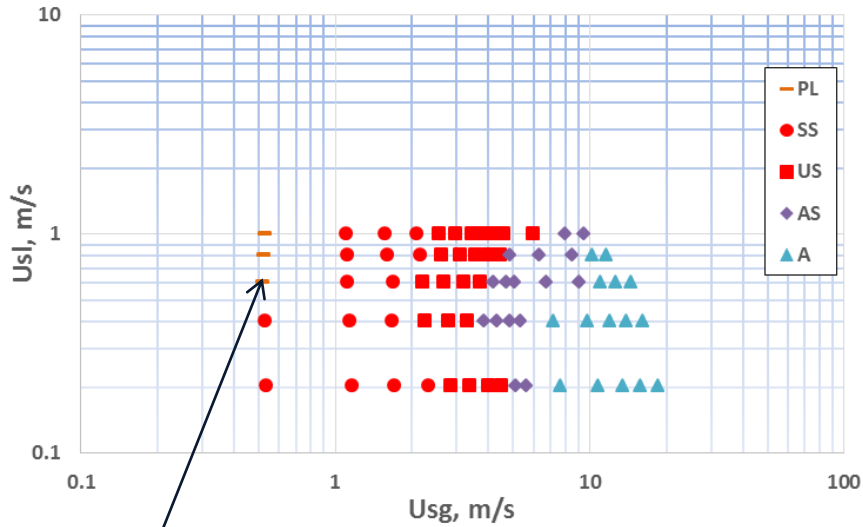


- Unstable slug flow in horizontal section
- 100D entrance length-based results again unreliable for Geometry 2



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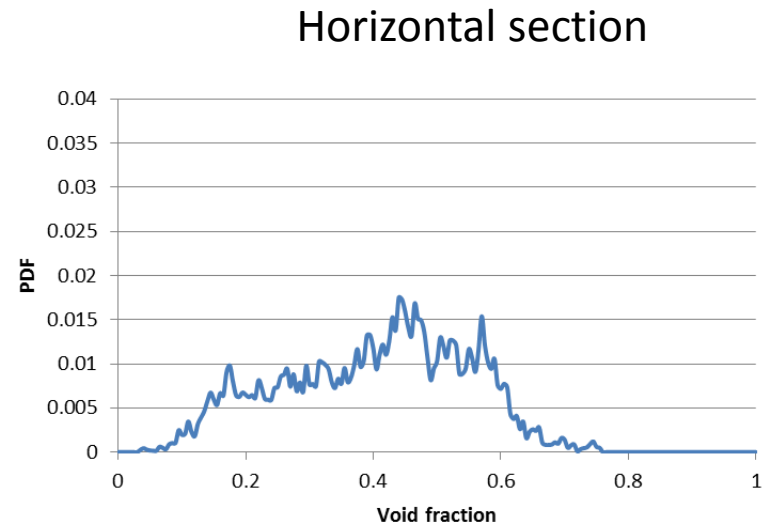
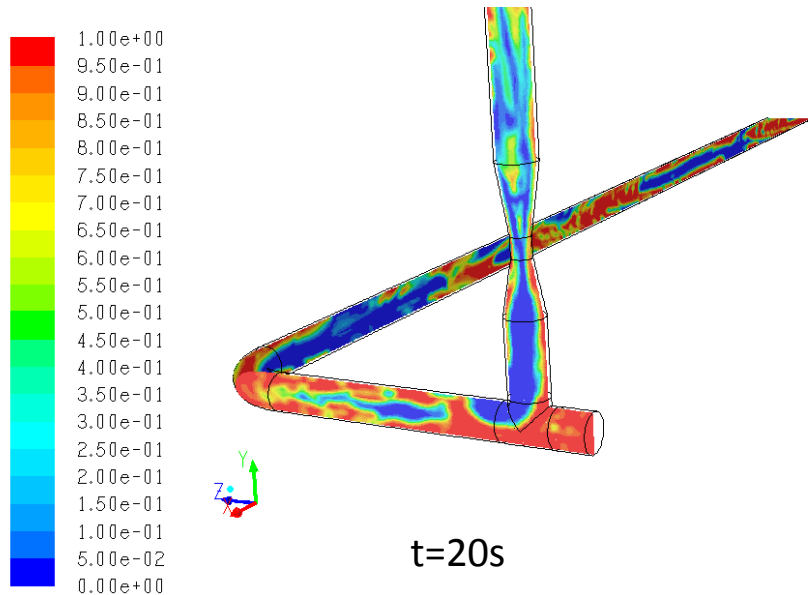
Geom 2 - 3D - 200D model - flow regime map (horizontal section)



PL: Plug flow
SS: Stable slug flow
US: Unstable slug flow
AS: Slug/Annular flow
A: Annular flow

$U_{sg} = 0.5 \text{ m/s}$,
 $U_{sl} = 0.6 \text{ m/s}$

Geom2, 3D - 200D entrance length – $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$



- Unstable flow in horizontal section
- The presence of the bend seems to affect the flow regime in upstream regions
- Additional tests are required to conclude fully



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Conclusion

- 100D entrance length is too short for the flow to be developed (for current test case: $U_{sg}=0.5\text{m/s}$, $U_{sl}=0.6\text{m/s}$)
- 2D results need to be carefully analysed since:
 - Flow is not symmetric
 - 3D effects are not accounted for
- However:
 - 2D results are sometimes closer to experiments (finer grid can be used)
 - 2D simulations usually faster than 3D ones

=> What is the most important, fast results or accurate results?
- Flow regime well predicted by 2D and 3D simulations (when entrance length is long enough) in the horizontal section
- Potential effect of bend on upstream flow
- Further work required:
 - Different flow conditions to be simulated
- European project EMRP'MultiFlowMet' - Phase 2 started in June 2017 with mostly the same partners



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Thank-you!!

Acknowledgments

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“ENG58 MultiFlowMet Multiphase Flow Metrology in the Oil and Gas Sector”

