

Evaluation of the Eulerian-Lagrangian Spray Atomization (ELSA) in spray simulations

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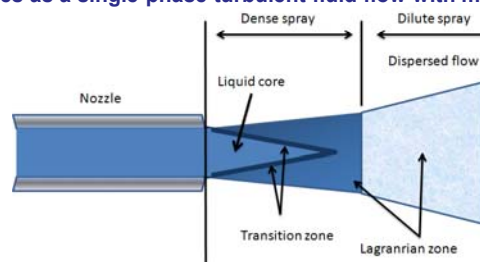
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CMT - Motores Térmicos (Department of thermal engine),
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ELSA modeling

The ELSA model is used for situations when it assumes the following hypotheses:


- In the situation of high-speed turbulent sprays where Reynolds and Weber numbers are high.
- And it exams a turbulent mixing process between the liquid and surrounding gaseous phases as a single-phase turbulent fluid flow with mean properties.



- **Eulerian mixture zone:** In this region (liquid core), liquid and gas phase are considered as a unique mixture flow. The classical Eulerian model is used to solve this single phase flow.
- **Transition zone:** switch from Eulerian to Lagrangian calculation.
- **Lagrangian zone:** classical Lagrangian tracking for droplets in the diluted spray zone and some regions of the Dense spray zone (adapted from Faeth et al., 1995)


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Agenda





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1. Objective
2. ELSA modeling
3. Boundary condition & Geometry
4. Mesh
5. Turbulent constant
6. Iso-surfaces
7. Axial velocity
8. Droplet velocity
9. Velocity profiles at different sections
10. Spray Penetration
11. Numerical Errors
12. Conclusions & Discussion



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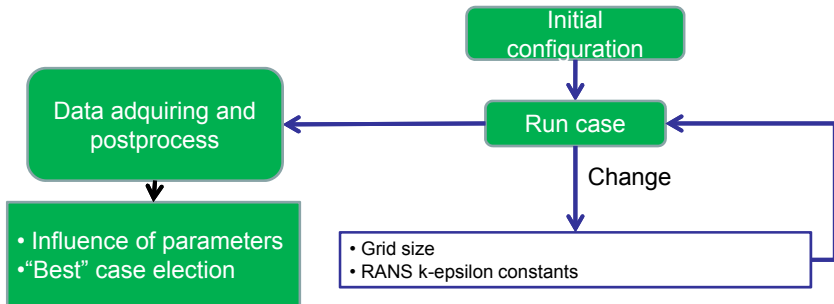

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Objective




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- To validate ELSA model implemented in Star-CD with a really well known case from CMT nozzles database CMT single-orifice nozzle database (non-evaporative conditions), Conical non-cavitating nozzles.
- Mesh independency and the effect of changing turbulent constant are explored.





```

graph TD
    A[Initial configuration] --> B[Run case]
    B --> C[Data acquiring and postprocess]
    C --> D["• Influence of parameters  
• 'Best' case election"]
    B --> E["• Grid size  
• RANS k-epsilon constants"]
    E -- Change --> B
  
```



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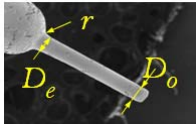


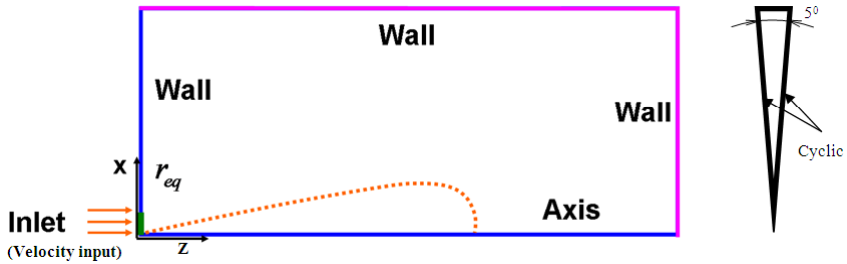
Boundary conditions & Geometry




- **Geometry**

	D_o (μm)	L/D	AR (%)	r/D
A	112	8,93	36,0	0,30



- **Basis Parameters**


Ambient pressure	Injection pressure	Temperature	Fuel density	Injection time
3.53 MPa	80 MPa	307.58K	822.10kg/m ³	3,1ms
- **Boundary conditions**





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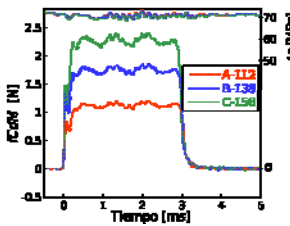
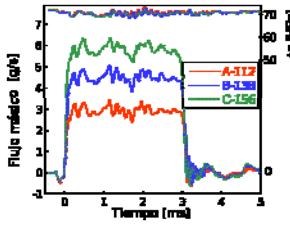




Velocity Input

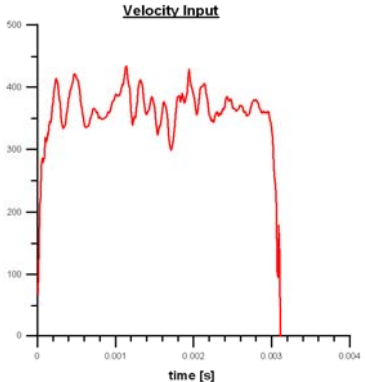



- **Velocity input, coming from CMT data (Injection rate & Momentum flux)**

}


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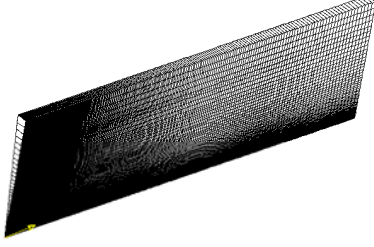




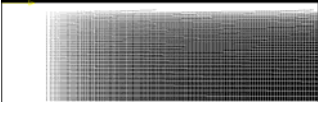
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Mesh

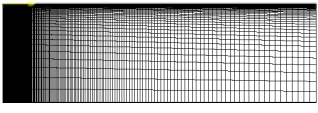




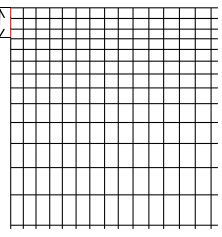
25 mm



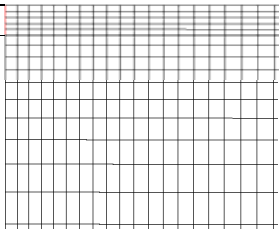
80 mm



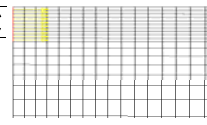
3-cell




5-cell




10-cell






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Mesh Parameter




Case number	# Cells at the ½ nozzle	# Axial cells	Axial ratio (Last/First)	# Radial cells	Axial ratio (First/Last)	Total Vertices	Total Cells
1	3	218	72	45	0.006	19,929	9,810
2	5	218	72	25	0.006	11,169	5,450
3	5	218	72	45	0.006	19,929	9,810
4	5	435	72	90	0.006	78,916	39,150
5	10	250	143	50	0.003	25,351	12,500
			First length		First length		
6	5	218	11.1 μm	25	11.1 μm	11,169	5,450



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Turbulent constant

The constants of the model are listed in the below table. We are using the classical constants used in most of the spray calculation. However, as it is also known few decades back (Pope, 1978), the classical value of Cε1 value of 1.44 causes an overprediction, the suggested value for rounded jet Cε1 = 1.60 and an average value of 1.52 are used in our calculation

	Cμ	Cε1	Cε2	Cε3	Cε4	Prandtl (K.E.)	Prandtl (Eps)
Turb 1	0.09	1.44	1.92	1.44	-0.33	1	1.219
Turb 2	0.09	1.52	1.92	1.44	-0.33	1	1.219
Turb 2	0.09	1.60	1.92	1.44	-0.33	1	1.219

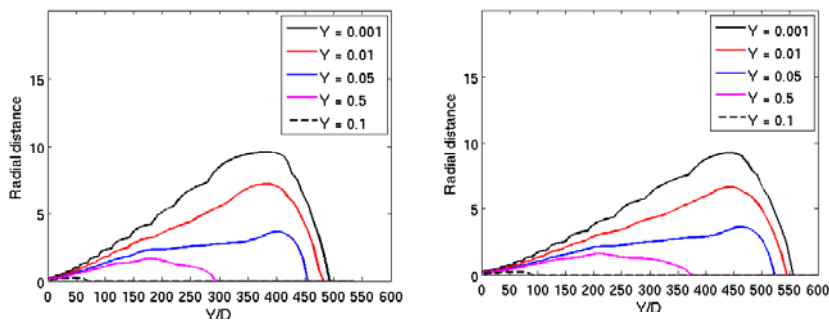
The RANS turbulent model chosen for our validation is the k-ε/ High Reynolds Number,

$$\frac{\partial \tilde{k}}{\partial t} + \tilde{u}_j \frac{\partial \tilde{k}}{\partial x_j} = C_\mu \frac{\tilde{k}^2}{\tilde{\epsilon}} \left(\frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial \tilde{u}_j}{\partial x_i} \right) \frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial}{\partial x_j} \left(\frac{C_\mu \tilde{k}^2}{\sigma_k \tilde{\epsilon}} \frac{\partial \tilde{k}}{\partial x_j} \right) - \tilde{\epsilon}$$

$$\frac{\partial \tilde{\epsilon}}{\partial t} + \tilde{u}_j \frac{\partial \tilde{\epsilon}}{\partial x_j} = C_{\epsilon_1} C_\mu \tilde{k} \left(\frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial \tilde{u}_j}{\partial x_i} \right) \frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial}{\partial x_j} \left(\frac{C_\mu \tilde{k}^2}{\sigma_\epsilon \tilde{\epsilon}} \frac{\partial \tilde{\epsilon}}{\partial x_j} \right) - C_{\epsilon_2} \frac{\tilde{\epsilon}^2}{\tilde{k}}$$



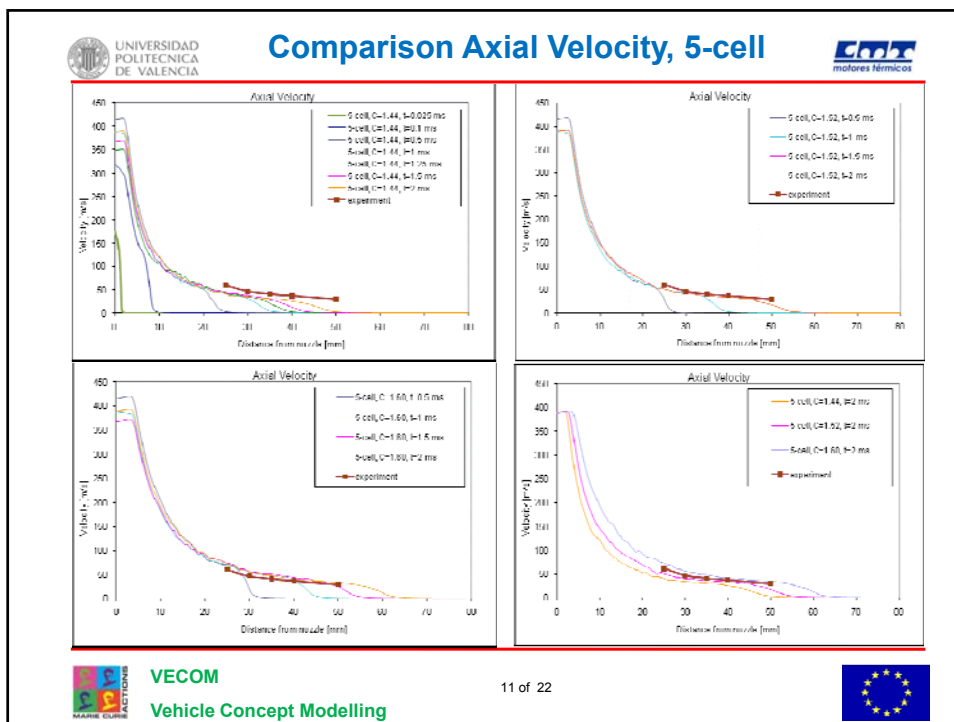
Iso-surfaces



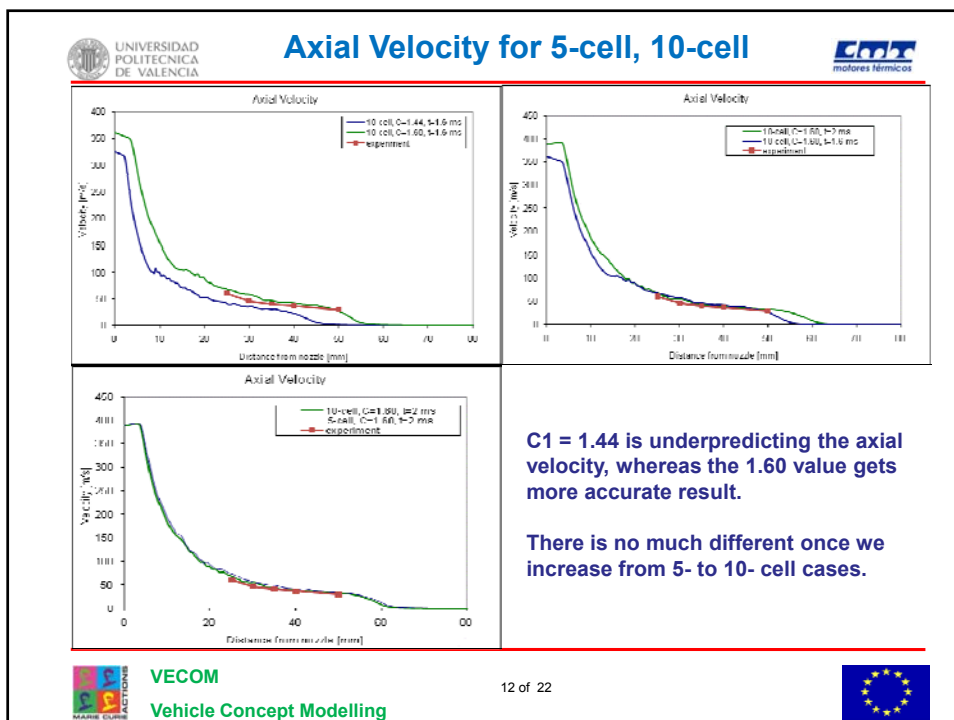
Comparison of iso-surfaces of 5-cell at 2ms, case 2 with C1=1.52 (left figure) and = 1.60 (right figure).

The longer axial distance of approximately 570 is obtained with = 1.60, while it is only 490 with = 1.52. It is clear from the figures, the effect of reduces spray dispersion and consequently increases spray penetration.





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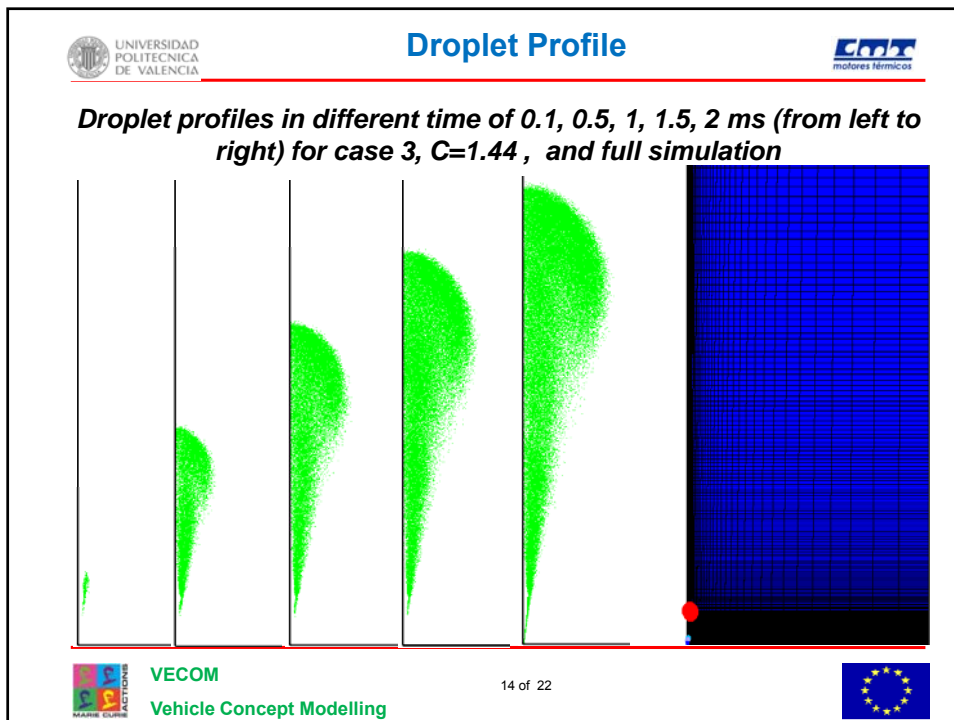
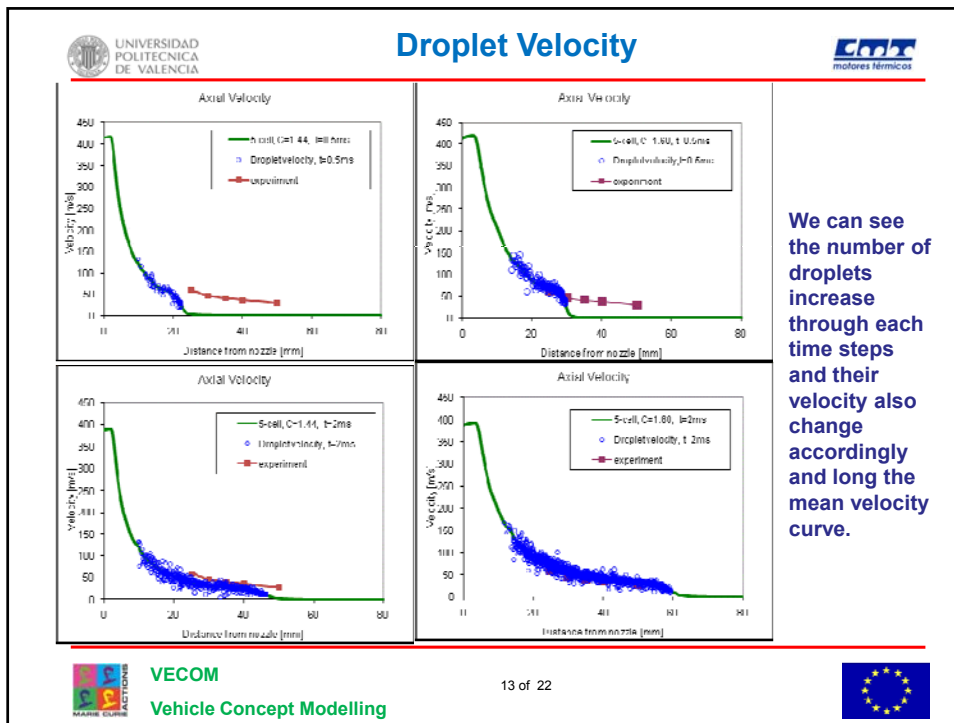


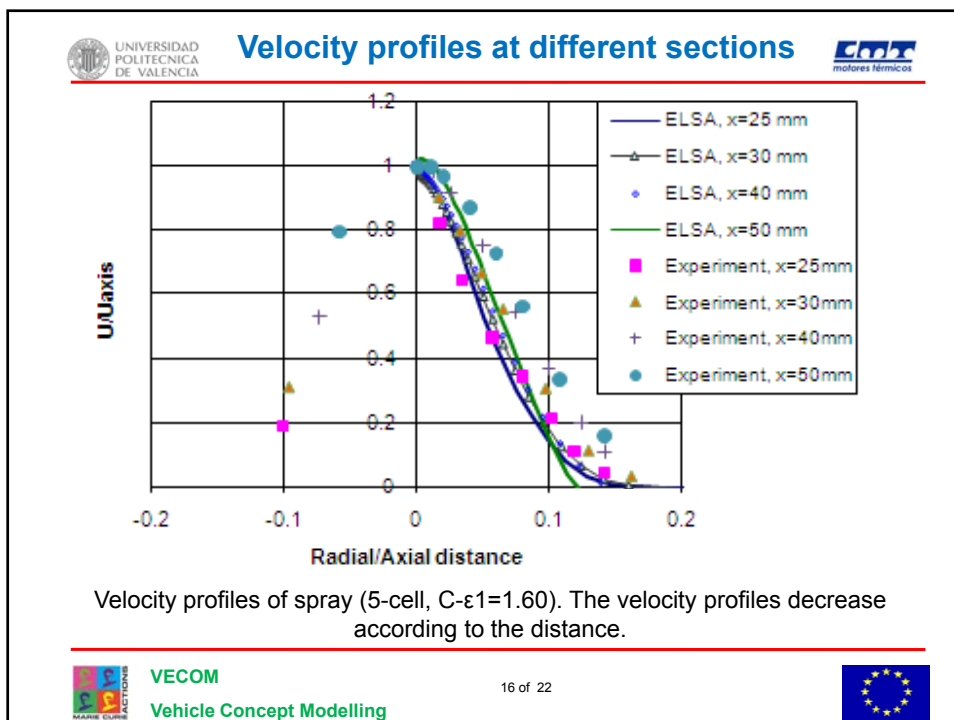
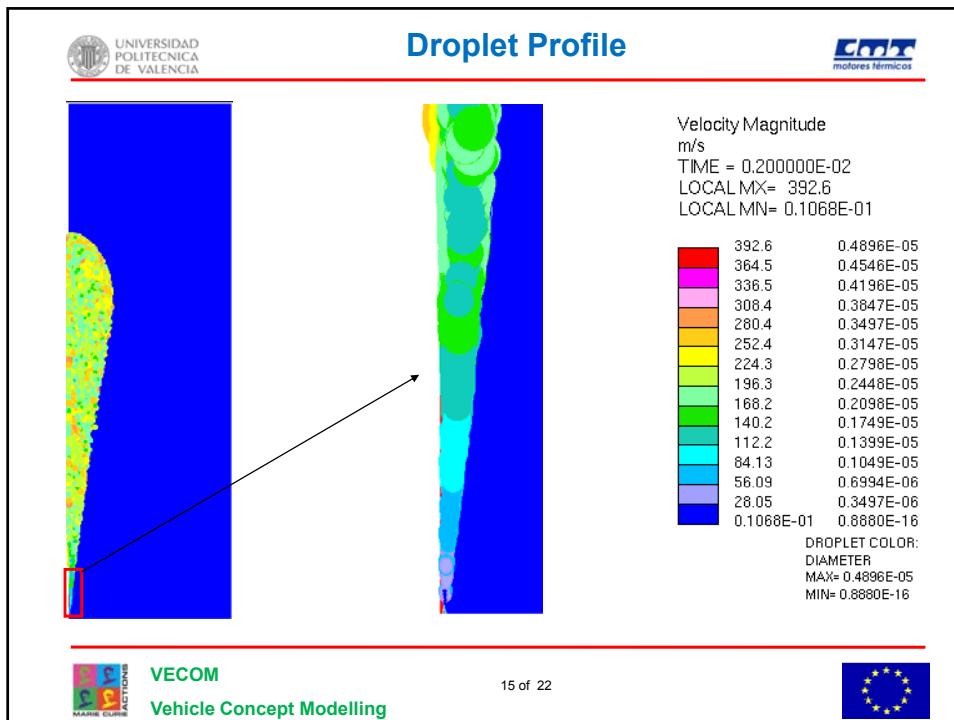
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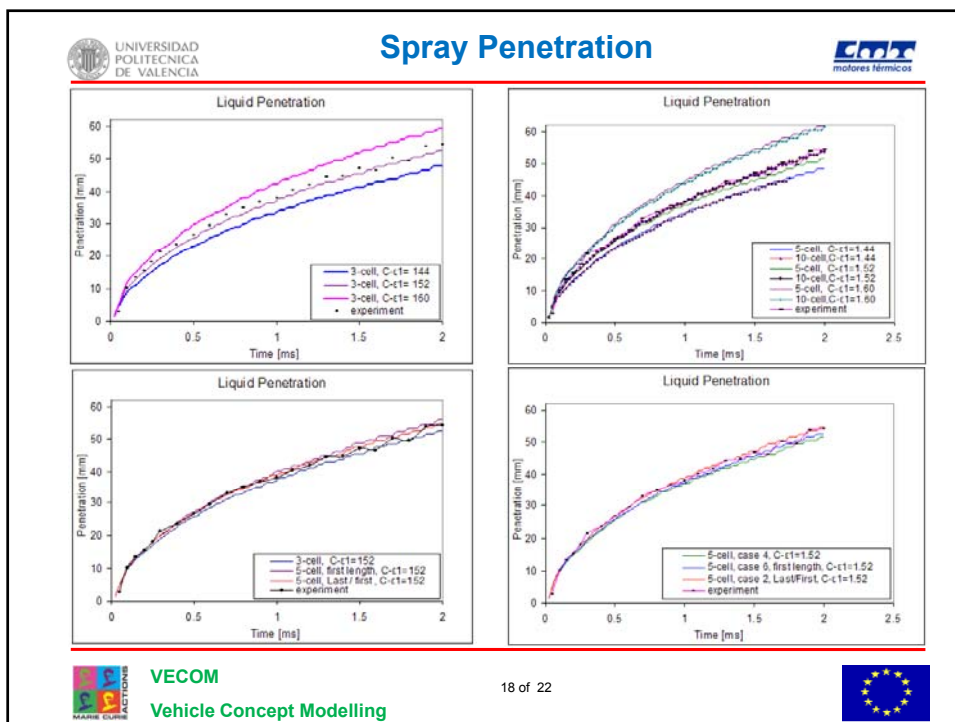
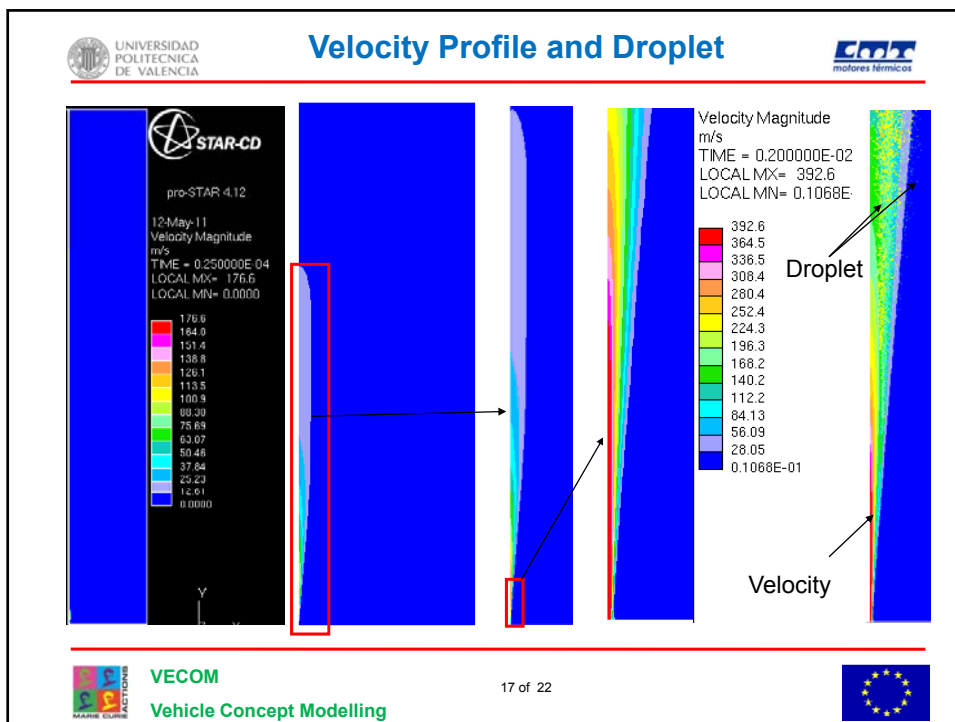


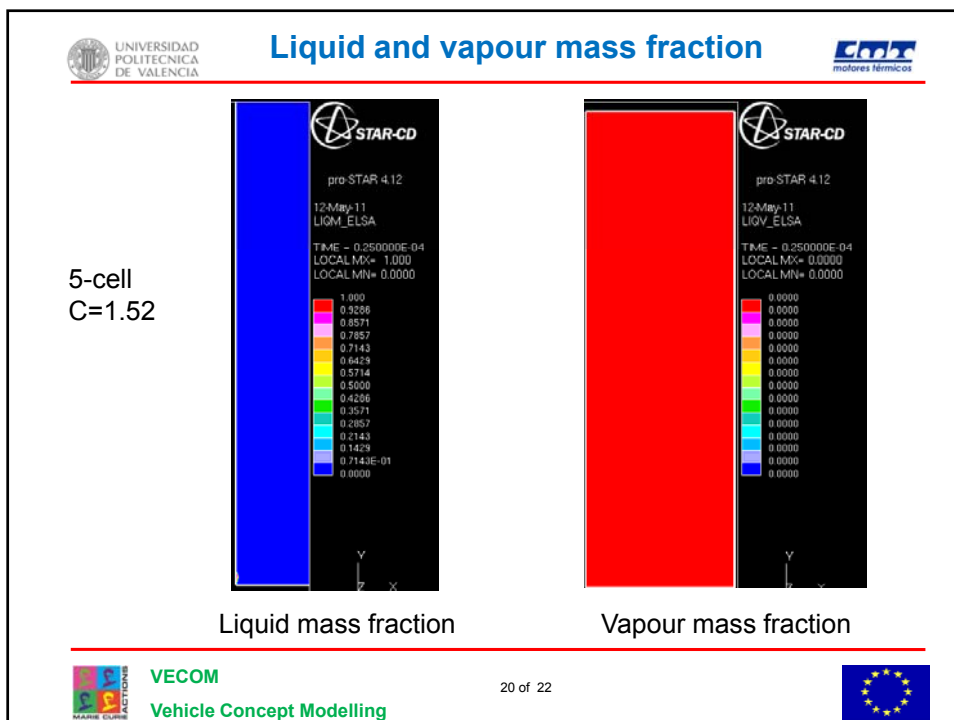
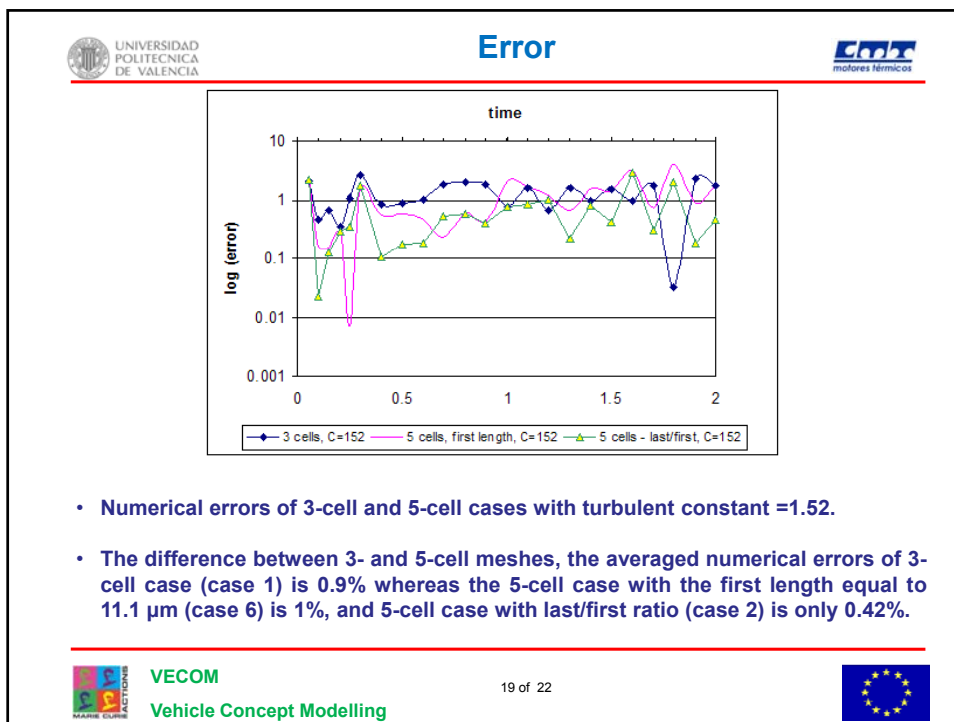
C1 = 1.44 is underpredicting the axial velocity, whereas the 1.60 value gets more accurate result.


There is no much different once we increase from 5- to 10- cell cases.













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Conclusion




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- There is no much different once we increase from 5- to 10- cell at the nozzle diameter.
- The variance between 3-cell case and 5-cell case is quite large in comparison with the discrepancy from 5-cell to 10-cell cases.
- Mesh independency is obtained with only 5- cell at the nozzle radius, which satisfies the reasonable result, permits a considerable saving in computational time and storage space. (Using the same constant =1.52 , it only takes 138451 seconds (~39 hours) to complete one parallel calculation consisted of 6 processors for 5-cell case, while it must need 517741 seconds (~ 144 hours) to complete one parallel calculation consisted of 12 processors for 10-cell case).
- C1 = 1.44 leads to underpredicting result, whereas the 1.60 value results more accurate result.
- The 5-cell mesh with last/first ratio consisted of 25 radial cells, and =1.52 is the optimal setup, it should be enough for using the future RANS calculation of this nozzle diameter.


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Thank you!



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Thank you for your kind attention!




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