UNIVERSITA' degli STUDI di ROMA
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FACOLTA' DI INGEGNERIA

Corso di Laurea in Ingegneria Energetica

FLUID DYNAMIC OPTIMIZATION OF AN UNDERGROUND STATION WITH THE SUPPORT OF THE IMMERSED BOUNDARY KARALIT CFD SOFTWARE

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Anno accademico: 2012/2013

SUMMARY

EXTRACT

INTRODUCTION

This work aims to corroborate a new Computational Fluid Dynamics software (CFD) produced by KARALIT. The introduction of CFD codes has allowed to overcome some difficulties associated with the scaled model in front of complex geometries.
KARALIT CFD, in fact, uses the Immersed Boundary Technique (IB) removing the pre-processing step and reducing the global computational times.
Thanks to collaboration between KARALIT and the University of Rome Tor Vergata, it has been possible to validate the software through independent testing.
In this extract, are reported the results from the software employed to study the internal flow produced by a passing train in the Cefalu's underground station.

ORIGINAL SCHEME AND CAD MODEL

Before reporting the tests results, it is interesting to observe the original scheme of Cefalu's gallery in relation with the CAD simplified model, employed to create the simulations (fig.1, fig.2).

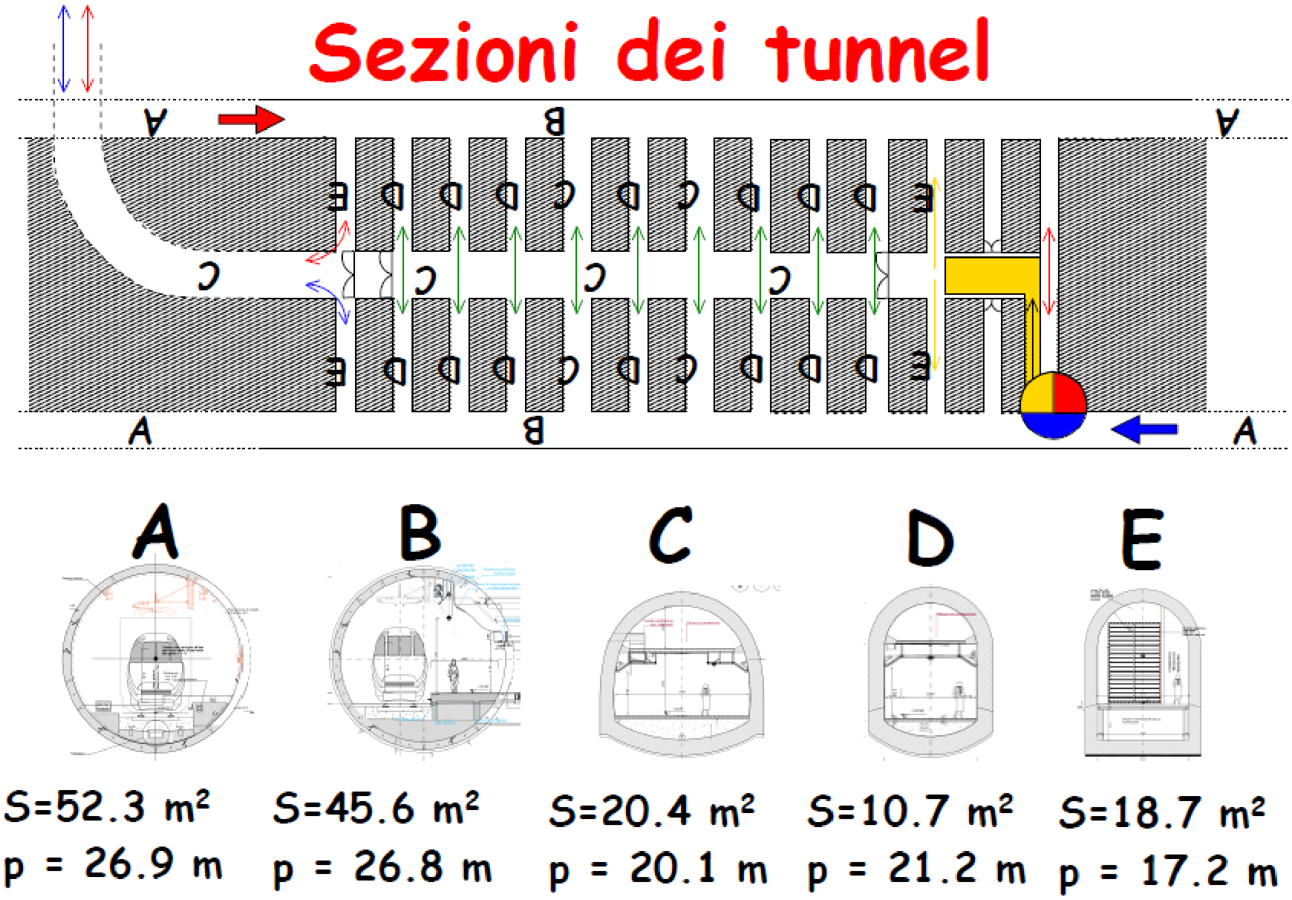


Figure 1: Original Scheme

- The A-section tunnels are the rail tracks.

- The D-section tunnels are the bypasses in order to slow and divert the air into the central duct (C-section).
- The chimneys (not visible in plant) expel the air into the atmosphere.

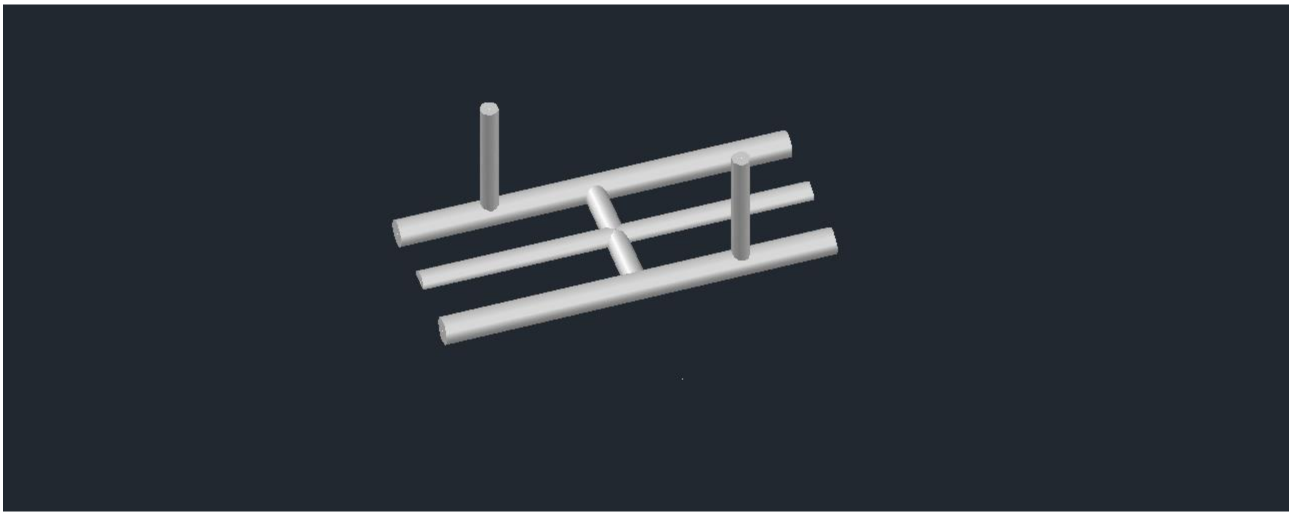
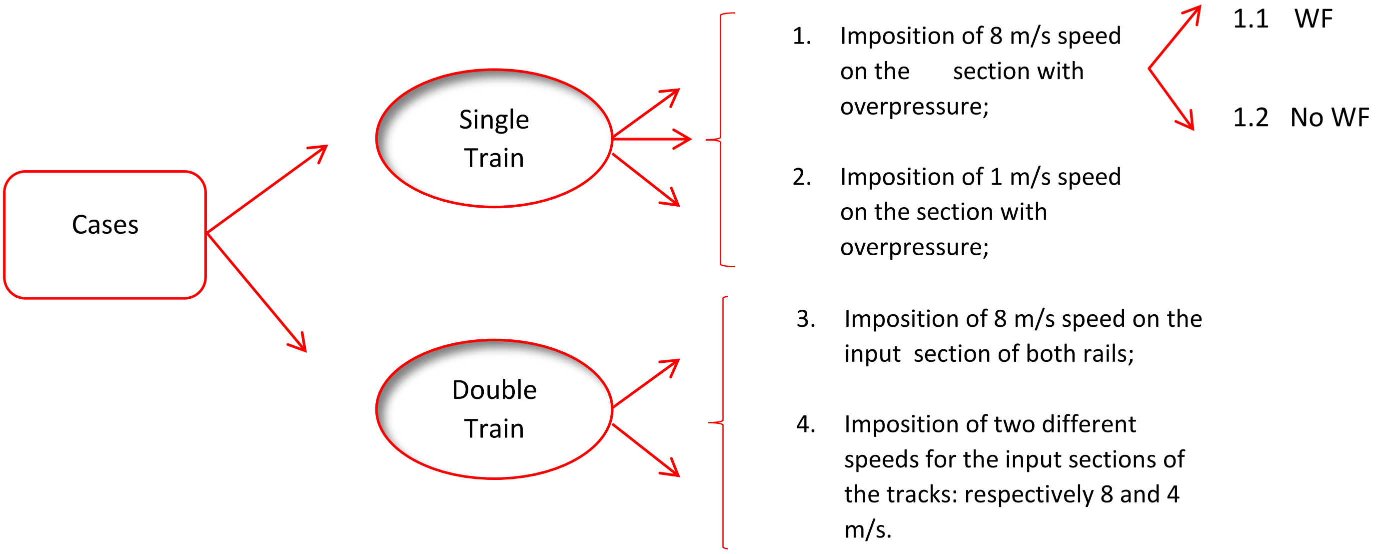


Figure 2: CAD model

As we can see, in the CAD model, only a single bypass appears. This choice has allowed the reduction of the computational cost without renouncing to the physical sense of the problem.

THE FLOW IN AN UNDERGROUND STATION AT VARYING VELOCITIES OF TRAINS

For the validation of KARALIT CFD, we have studied the five cases reported in Figure 3.



1. Imposition of 8 m/s speed on the section with overpressure;
2. Imposition of 1 m/s speed on the section with overpressure;
3. Imposition of 8 m/s speed on the input section of both rails;
4. Imposition of two different speeds for the input sections of the tracks: respectively 8 and 4 m/s.

Figure 3: Summary table of cases

As we can see, in the first three examples, a single train travels through the gallery, producing an asymmetric airflow in the station.

The cases 1.1 and 1.2 are different only for the introduction of a wall function (WF) in the first one. This function includes the evaluation of the intrinsic and geometrical imperfections through the gallery.
In the last two cases, there are two trains travelling simultaneously at the same (3.) or different speed (4.). We can see, in the foreground of figures 4 and 5, the window used to create the new cases and the main window of the program where it is possible to manage the settings. In particular, we can choose the type of application (internal flow, external flow…), the boundary conditions of the body and the simulation properties, the manipulation of the object through a set of tools (EDIT, DIVIDE and SURFACE SELECTION) etc. …

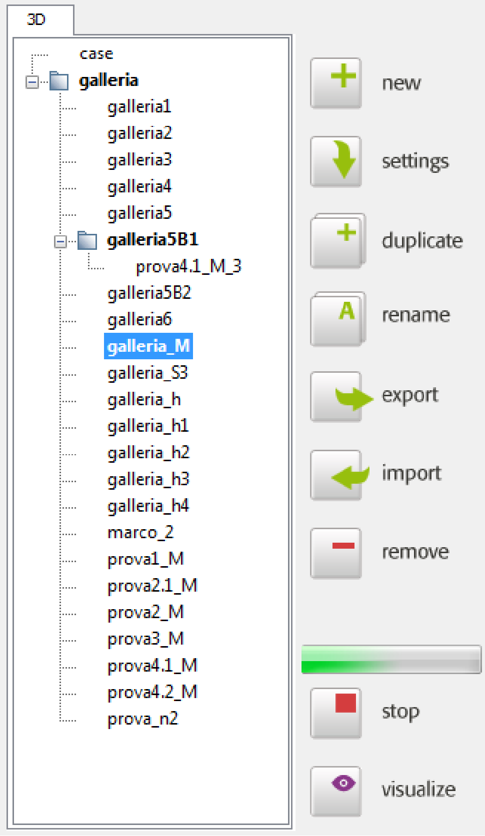
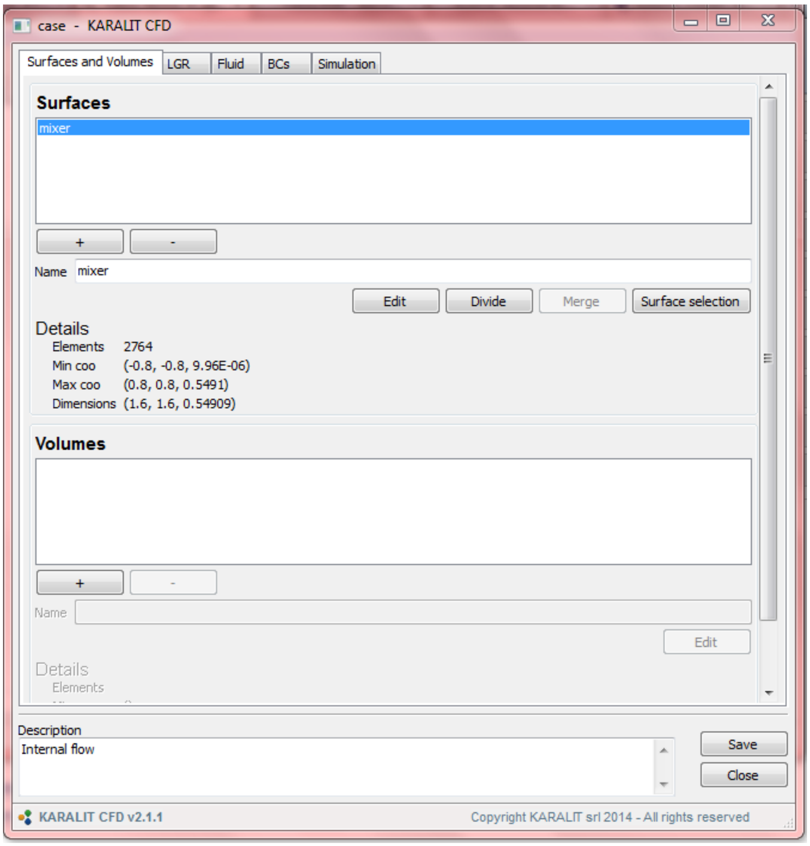


Figure 4



Name mixer

Details
Elements 2764
Min coo (-0.8, -0.8, 9.96E-06)
Max coo (0.8, 0.8, 0.5491)
Dimensions (1.6, 1.6, 0.54909)

Name

Details
Elements

Description
Internal flow

Figure 5

ASSUMPTION

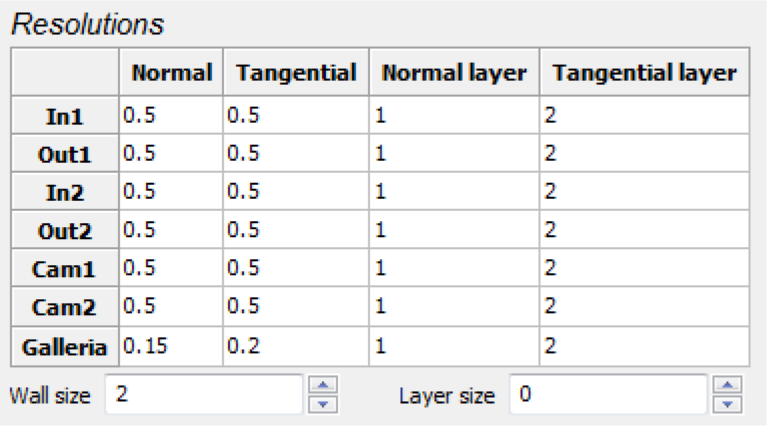
Every simulation has been made with the following assumption:

a. Viscous turbulent fluid
b. Ideal fluid
c. Characteristics of the simulation
- Density= 1,225 $\frac{Kg}{m^3}$
- Components of the velocity vector→ $V_x=1\,\frac{m}{s}$, $V_y=1\,\frac{m}{s}$, $V_z=1\,\frac{m}{s}$
- Pressure p = 101325 Pa
- Temperature T = 228,15 K

d. Integration
- CFL = 5
- Implicit Gauss-Seidel

- Scheme: 2nd order Symmetric TVD
- Maximum number of iterations equal to 10000
- Monitoring x-momentum residual, stop when convergence reaches 10^{-4}.

In figure 6, are reported the characteristics of the grid for each body surfaces:



Resolutions

	Normal	Tangential	Normal layer	Tangential layer
In1	0.5	0.5	1	2
Out1	0.5	0.5	1	2
In2	0.5	0.5	1	2
Out2	0.5	0.5	1	2
Cam1	0.5	0.5	1	2
Cam2	0.5	0.5	1	2
Galleria	0.15	0.2	1	2

Wall size 2

Layer size 0

Figure 6: LGR

RESULTS

Each simulation has reached the convergence (residual equal to 10^{-4}) with a positive feedback in term of conservation of the mass flow rate.

CASE 1: Mass Flow Rate and Velocity

In the following figures, we can see the difference between the two graphics of the case with and without WF.

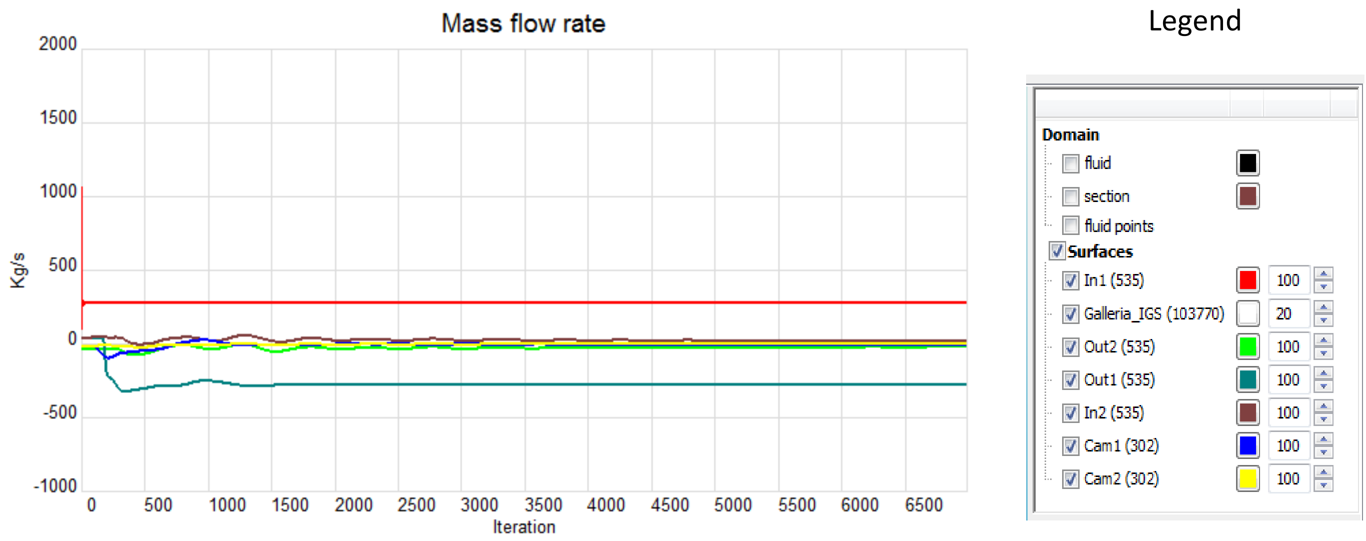


Figure 7: Mass Flow Rate of a Single Train in Station (v= 8m/s) with WF.

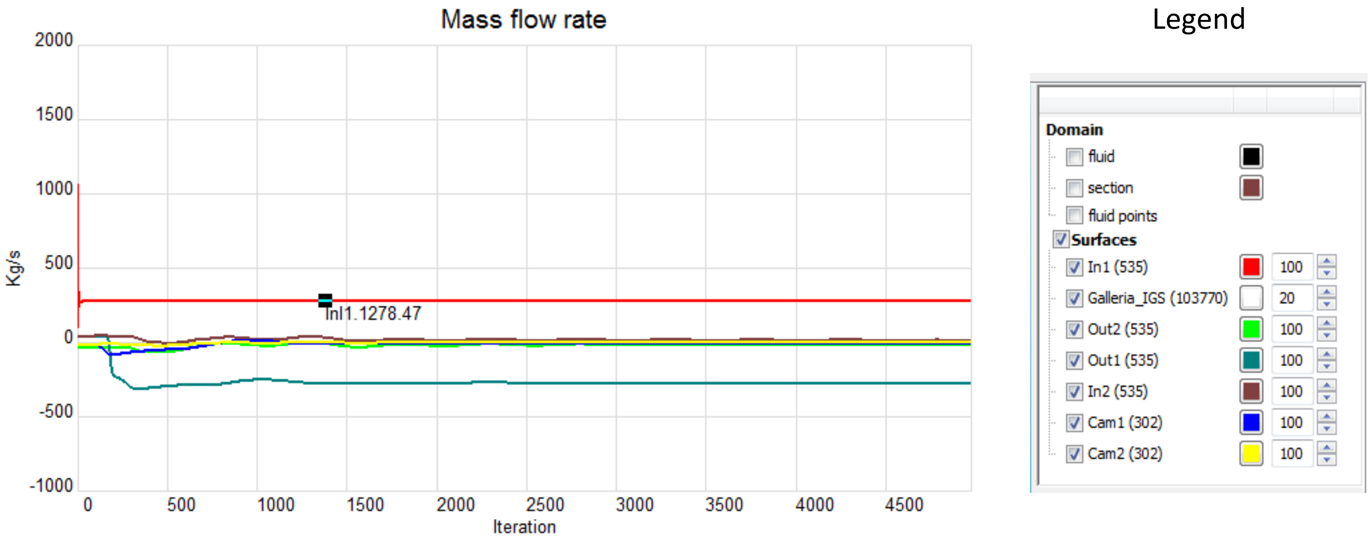
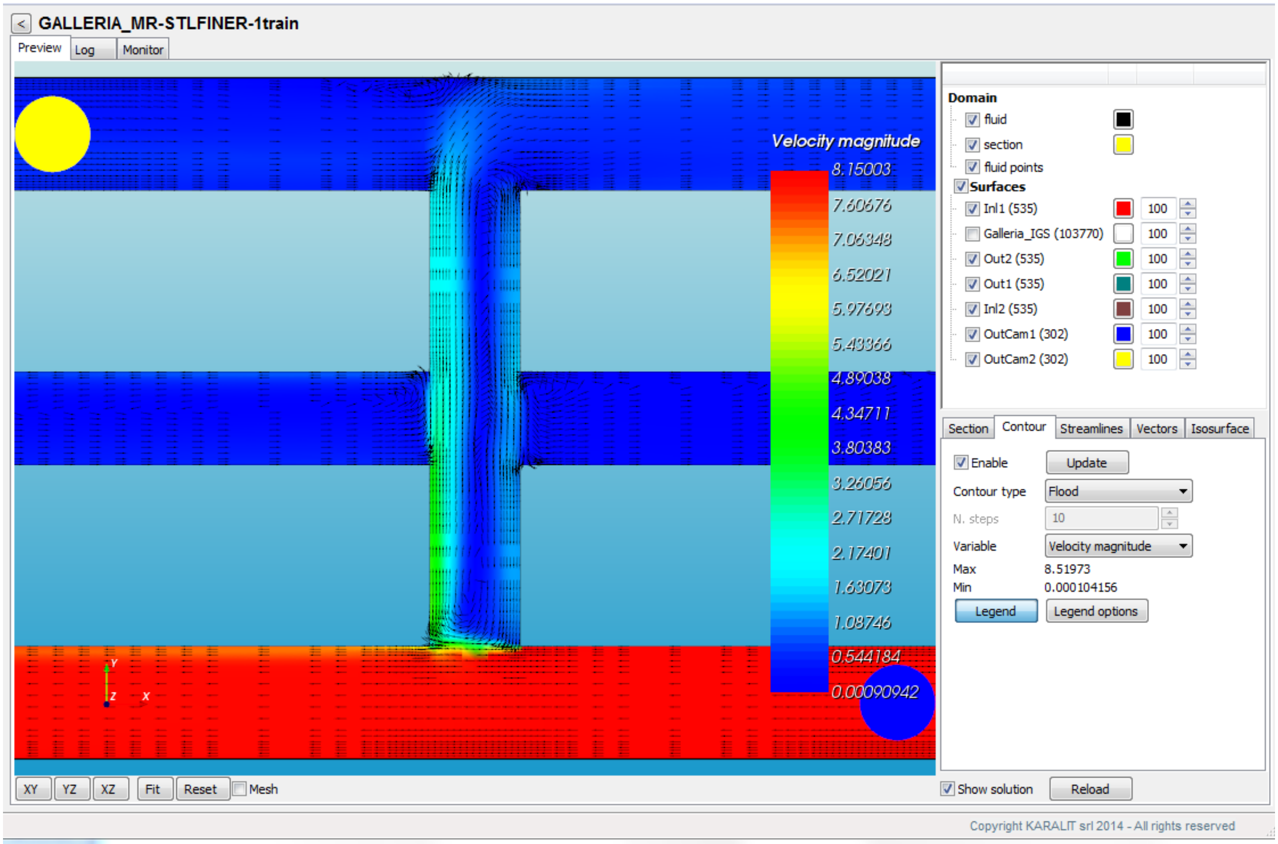


Figure 8: Mass Flow Rate of a Single Train in Station (v= 8m/s) without WF.

In fact, with the introduction of WF, have also been added the load losses by friction. Therefore, the graphic of mass flow rate is more stable and the simulation time is longer.

The figure 9 and 10 have been exported from the software for a section of the plane XY=4. It is interesting to note that the differences between the velocity fields of the two cases are minimal.

The speed values, in fact, are slightly higher in the central tunnel of the example reported in figure 9 (less than 1 m/s). It is evident that the WF doesn't introduce significant changes in the velocity field: this fact may require a deeper evaluation which will be carried on in future works.



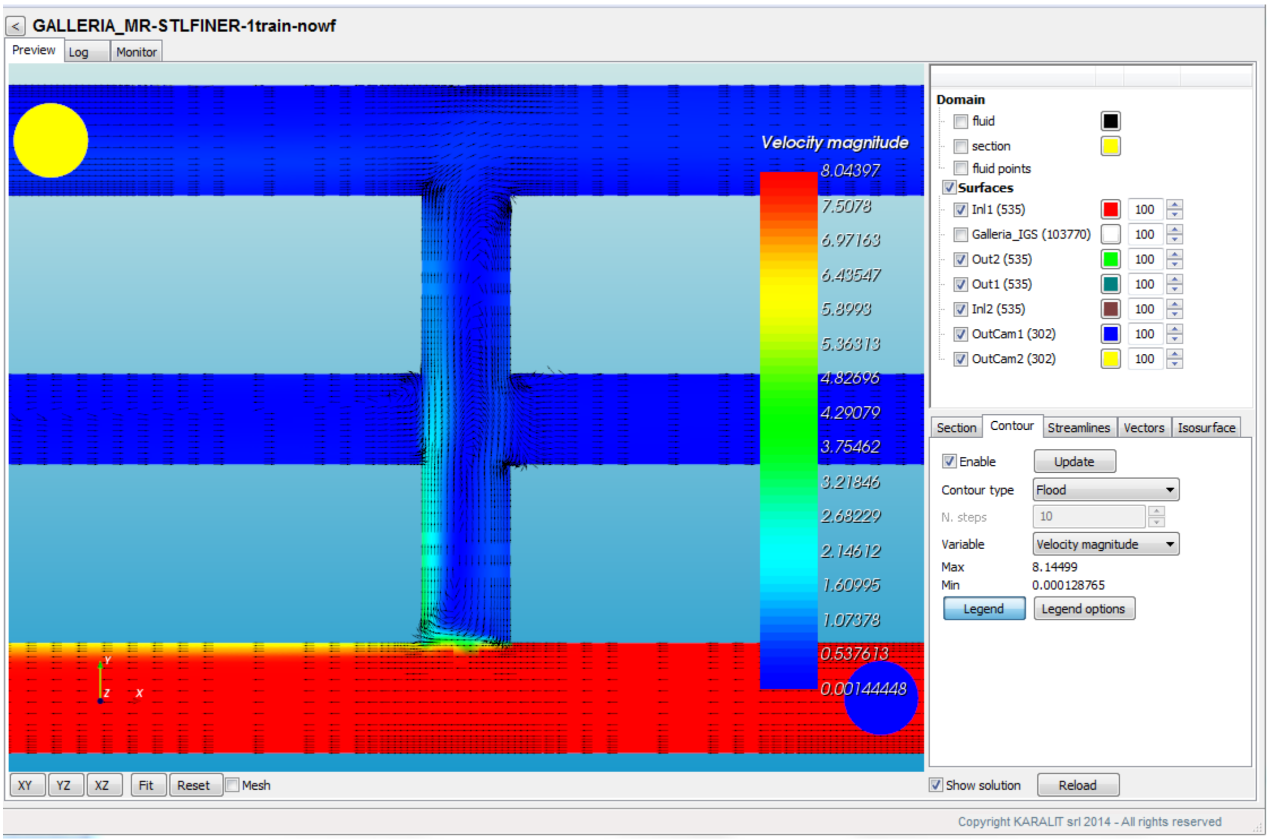
☐ Mesh

☑ fluid
☑ section
☑ fluid points
☑ Surfaces
☑ Inl1 (535) 100
☐ Galleria_IGS (103770) 100
☑ Out2 (535) 100
☑ Out1 (535) 100
☑ Inl2 (535) 100
☑ OutCam1 (302) 100
☑ OutCam2 (302) 100

☑ Enable
Contour type Flood
N. steps 10
Variable Velocity magnitude
Max 8.51973
Min 0.000104156

☑ Show solution

Figure 9: Velocity Field of a Single Train in Station (v= 8m/s) with WF.



☐ Mesh

☐ fluid
☐ section
☐ fluid points
☑ Surfaces
☑ Inl1 (535) 100
☐ Galleria_IGS (103770) 100
☑ Out2 (535) 100
☑ Out1 (535) 100
☑ Inl2 (535) 100
☑ OutCam1 (302) 100
☑ OutCam2 (302) 100

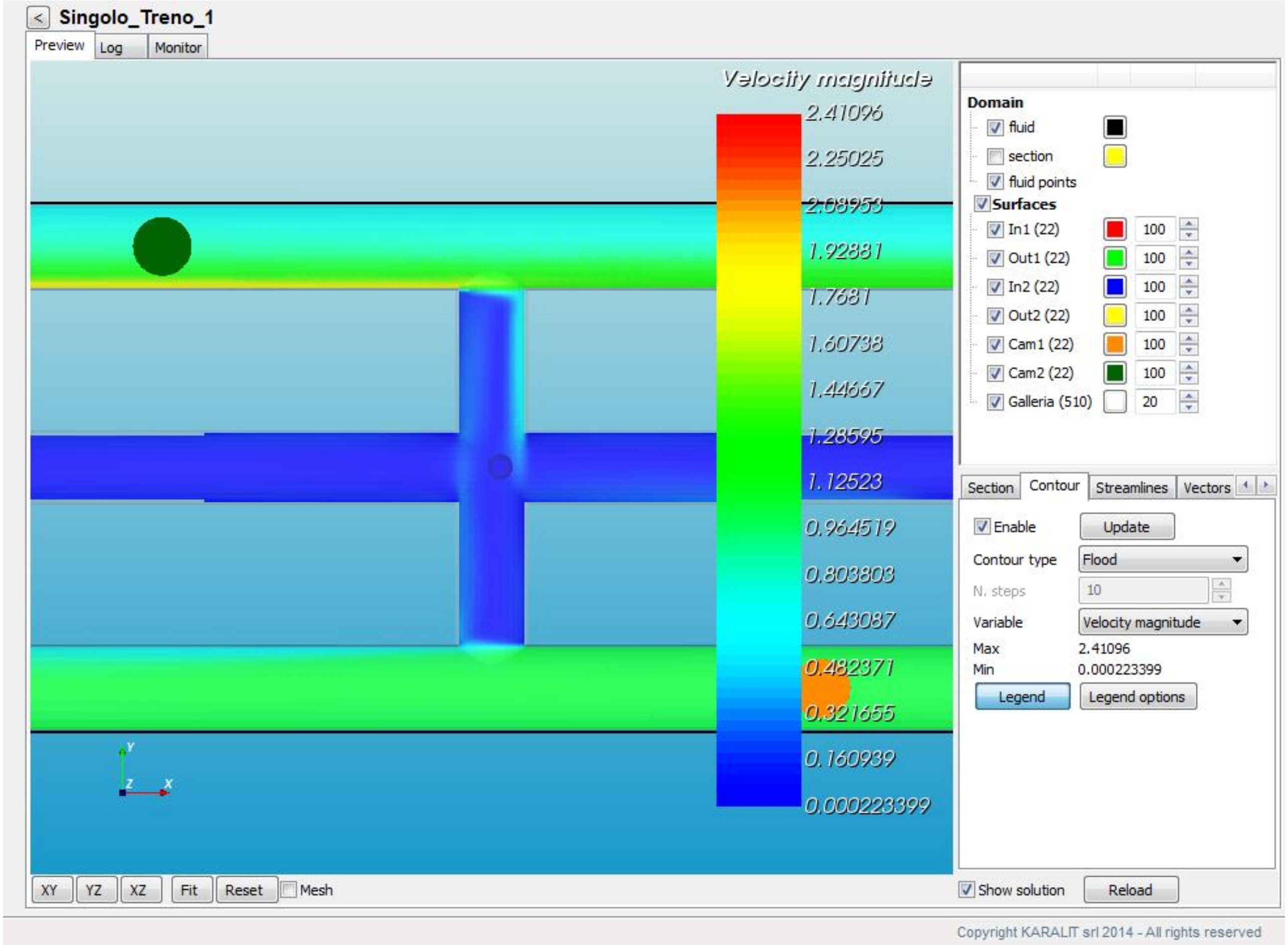
☑ Enable
Contour type Flood
N. steps 10
Variable Velocity magnitude
Max 8.14499
Min 0.000128765

☑ Show solution

Figure 10: Velocity Field of a Single Train in Station (v= 8m/s) without WF.

CASE 2: Velocity

In this case, due to the slow velocity of the inbound train, the values of velocity field are radically lower. As we could expect, the presence of a single train travelling through the gallery, produces an asymmetrical velocity field respect the x-axis of the body.



☑ Enable
Contour type: Flood
N. steps: 10
Variable: Velocity magnitude
Max 2.41096
Min 0.000223399

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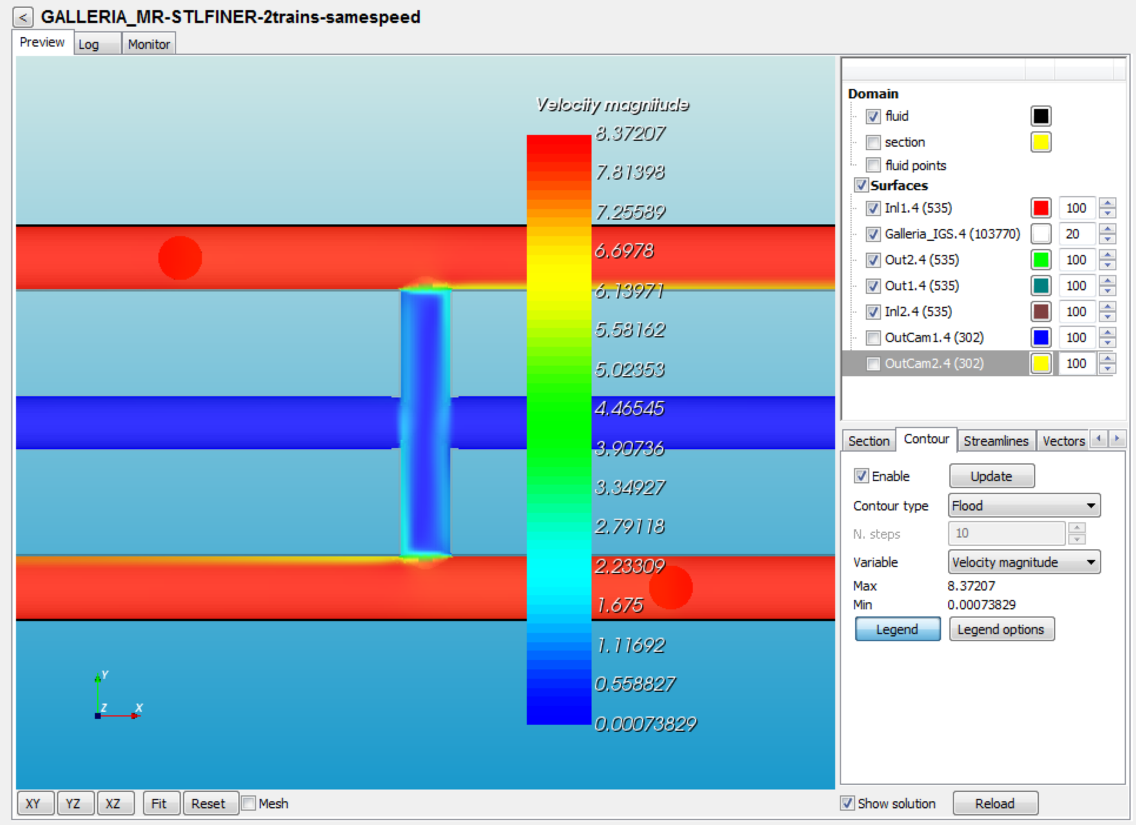
Figure 11: Velocity Field of a Single Train in Station (v= 1m/s).

CASE 3-4: Velocity

In the figures 12 and 13, have been reported the graphics of velocity field in the last two simulations. It's useful to point out the total symmetry of the solution respect the geometrical axis of the body.



Domain
☑ fluid
☐ section
☐ fluid points
☑ **Surfaces**
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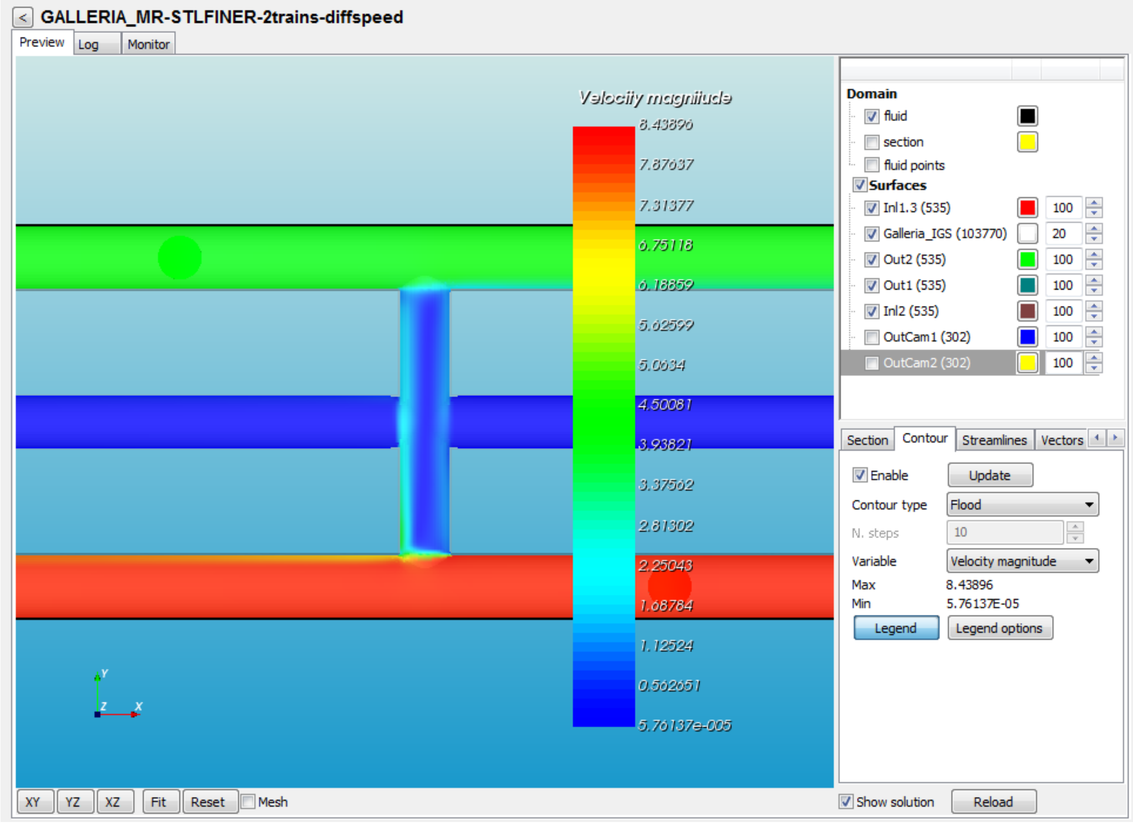
☑ Galleria_IGS.4 (103770) 20
☑ Out2.4 (535) 100
☑ Out1.4 (535) 100
☑ Inl2.4 (535) 100
☐ OutCam1.4 (302) 100
☐ OutCam2.4 (302) 100

☑ Enable
Contour type: Flood
N. steps: 10
Variable: Velocity magnitude
Max 8.37207
Min 0.00073829
☐ Mesh
☑ Show solution

Figure 12: Velocity Field of Two Trains Travelling at the same Speed (v= 8m/s) in Station



Domain
☑ fluid
☐ section
☐ fluid points
☑ **Surfaces**
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☑ Galleria_IGS (103770) 20
☑ Out2 (535) 100
☑ Out1 (535) 100
☑ Inl2 (535) 100
☐ OutCam1 (302) 100
☐ OutCam2 (302) 100

☑ Enable
Contour type: Flood
N. steps: 10
Variable: Velocity magnitude
Max 8.43896
Min 5.76137E-05
☐ Mesh
☑ Show solution

Figure 13: Velocity Field of Two Trains Travelling at different Speed (v= 8 and 4 m/s) in Station

CONCLUSION

Analyzing the results of the simulation (partially presented in this extract), we can consider the software validated.
In fact, the obtained data respect perfectly the physical sense of the problem. An important factor, which represents a program strong point, is the intuitive interface to enter the simulation parameters. Thanks to it, the user can choose the best setting for the test optimization without programming. Moreover the immerse boundary method allows to perform objects with complicated shape, breaking down considerably the setup time. Definitively, the remarkable ease of use and the method employed by this software could represent an excellent alternative to the tools usually applied in the simulation of the industrial application.

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