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STUDY OF CARBONATIC SCALE IN COMPLETION TOOLS THROUGH MODELING AND SIMULATION TECHNIQUES

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1. INTRODUCTION

The pursuit of hydrocarbons in increasingly complex exploration scenarios has demanded new predictive computational tools. In this context, many researchers have spent a lot of efforts to develop mathematical models in order to predict scaling in completion equipment. According to Graham *et al* (2013), narrow channels impel the flowing fluid in downhole valves, which considerably increases the wall shear. The flow through these channels contributes dramatically to the pressure drop during the hydrocarbon production, especially in high flow rate wells (Maciel, 2017). According to Brownlee *et al* (2001), and Graham *et al* (2013), this phenomenon favors the precipitation of calcium carbonate in the neighborhood, or inside these elements, and may reduce or completely block production by full obstruction. Thus, knowing the fluid dynamics in such equipment is crucial for flow assurance, mainly regarding the quantification of the pressure drop, against the variation of operational and geometric parameters of such tools.

Through the computational fluid dynamics technique (CFD), this work aims to study the effect of geometric variables of a generic downhole valve and the effect of the influx flow rate and fluid properties on the minimization of the overall pressure differential in the valve. Through the discrete phase modeling (DPM), the effect of the flow intensity on the transport of the solids to the internal adhesion surfaces is verified, and which of these surfaces are more favorable to the scaling phenomenon. By comparative analysis, it is shown that the volumetric influx rate is the most significant factor in the pressure drop (response variable). For the geometric factors, the effect of the number of connections between the annular outer region and internal tube presented a greater relevance compared to the chamfer angulation effect considered at the inlet of these connections.

2. METHODOLOGY

The strategy for this study is centered on the application of numerical computational simulation (CFD) technique. The equations describing macroscopically the turbulent flow in the control volume are numerically solved both in space and time, in the case of transient phenomena.

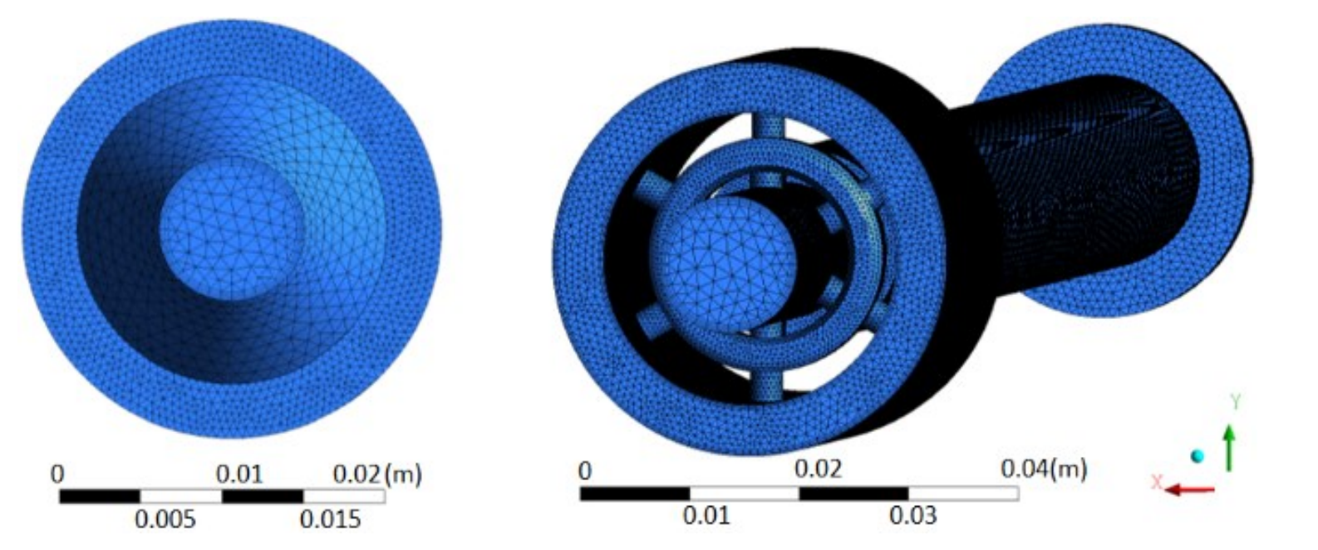

Figure 1. Representation of the computational mesh (source: the author).

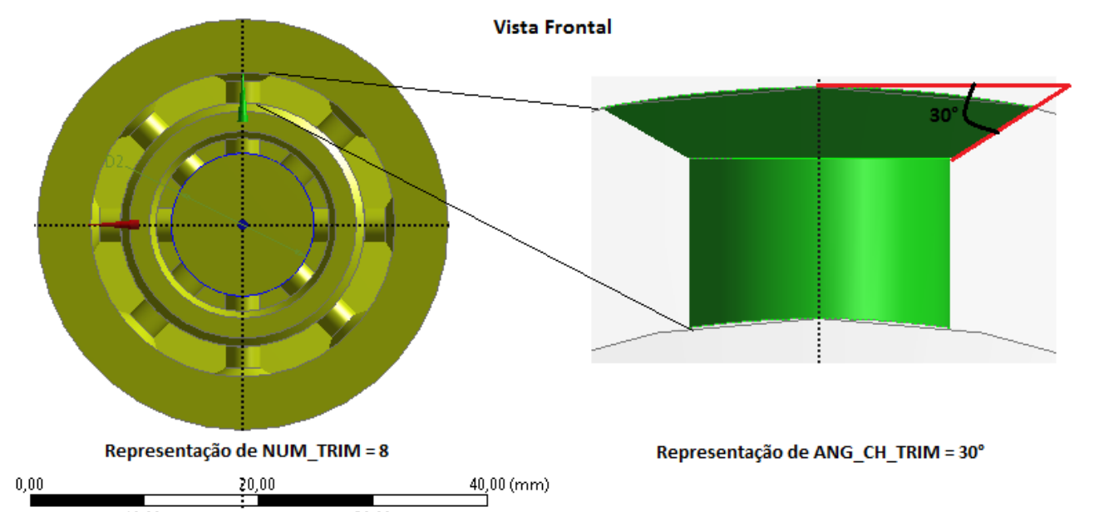

Figure 2. Representation of the TRIM region, highlighting the geometric parameters NUM_TRIM (equal 8) and ANG_CH_TRIM (equal 30°). (source: the author).

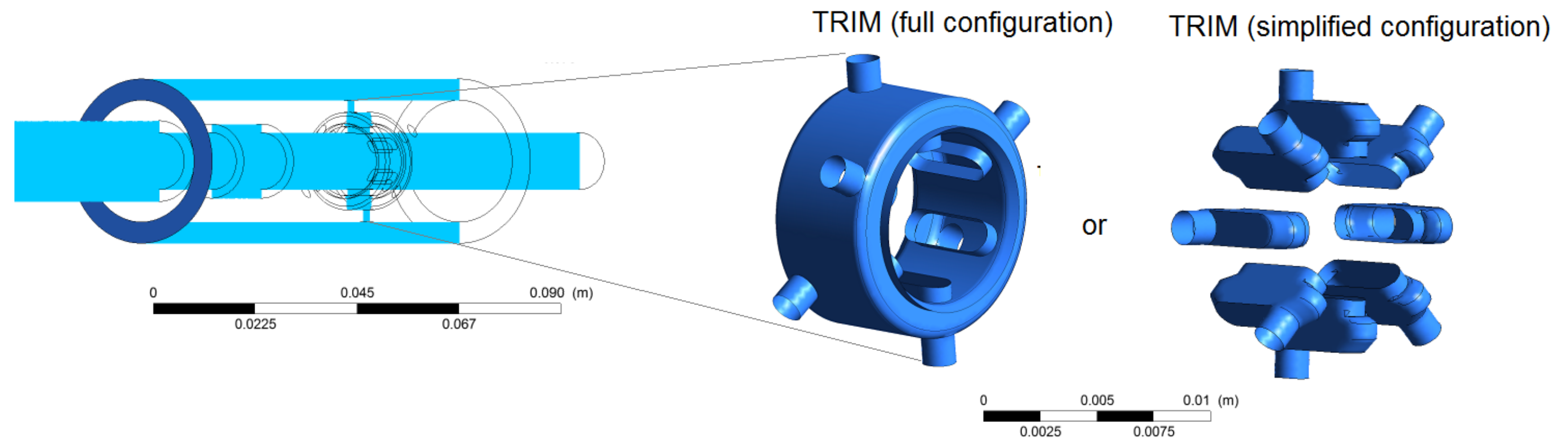

Figure 3. Representation of the control volume and its border regions.

Table 1. Simulations parameters.

Case	Veloc. [m/s]	Visc. [cP]	NUM_TRIM [-]	ANG_CH_TRIM [º]
1	1	15	8	60
2	5	15	8	60
3	10	15	8	60
4	5	1	8	60
5	5	15	8	60
6	5	30	8	60
7	5	15	6	60
8	5	15	8	60
9	5	15	10	60
10	5	15	8	30
11	5	15	8	60
12	5	15	8	90
13	1	1	8	90
14	5	1	8	90

The solver ANSYS FLUENT® 18.02 is used to perform the computational experiments, according to Table 1. For this purpose, the following boundary conditions and mathematical models are considered:

- non-slip condition on the walls of the control volume (flow's speed magnitude equal to zero at the wall boundaries);
- fluid's specific mass of 998 kg/m³;
- turbulent *k*-ε Realizable model with Enhanced Wall Treatment, detailed in Fluent (2017);
- time step of 0.001 s;
- gravitational field magnitude of 9.81 m/s² oriented to (0, -Y, 0);
- SIMPLE scheme for coupling pressure and flow velocity, detailed in Fluent (2017);

The DPM injection set up follow the main sets:

- Diameter of the spherical crystals of 50 μm;
- Discrete phase's specific mass of 2800 kg/m³ (calcium carbonate);

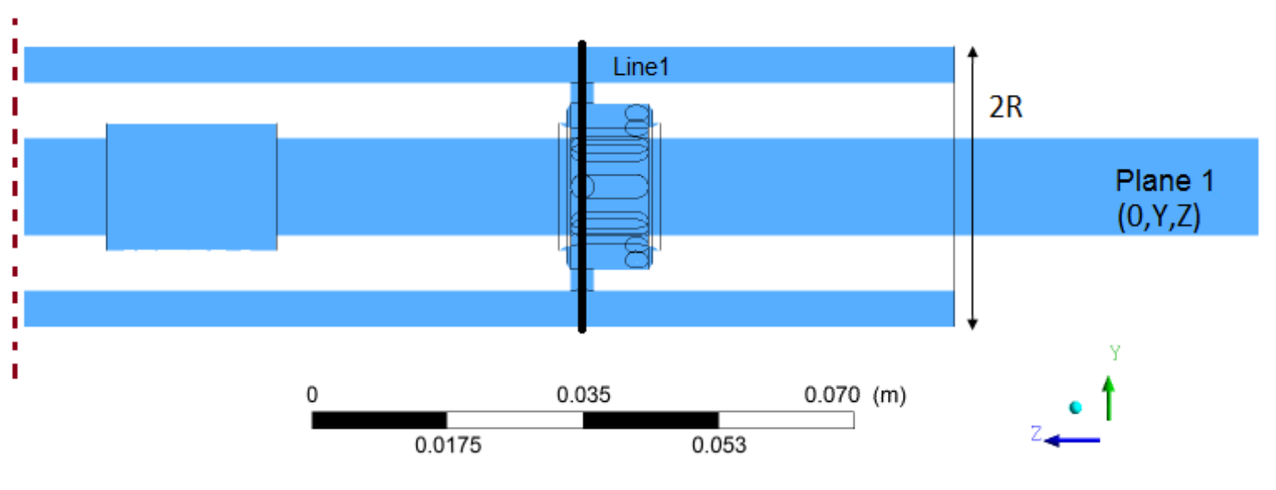

Figure 4. Location of Line 1; R corresponds to 0.018m.

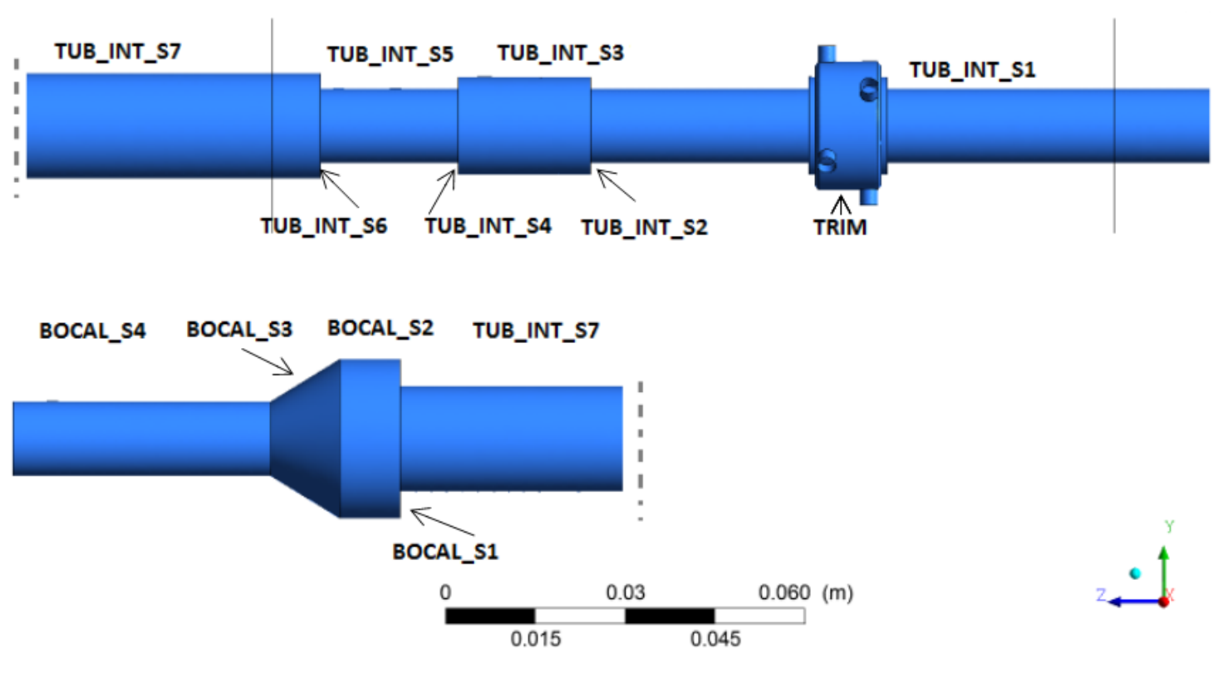

Figure 5. Representation of the internal boundaries of the control volume.

3. RESULTS

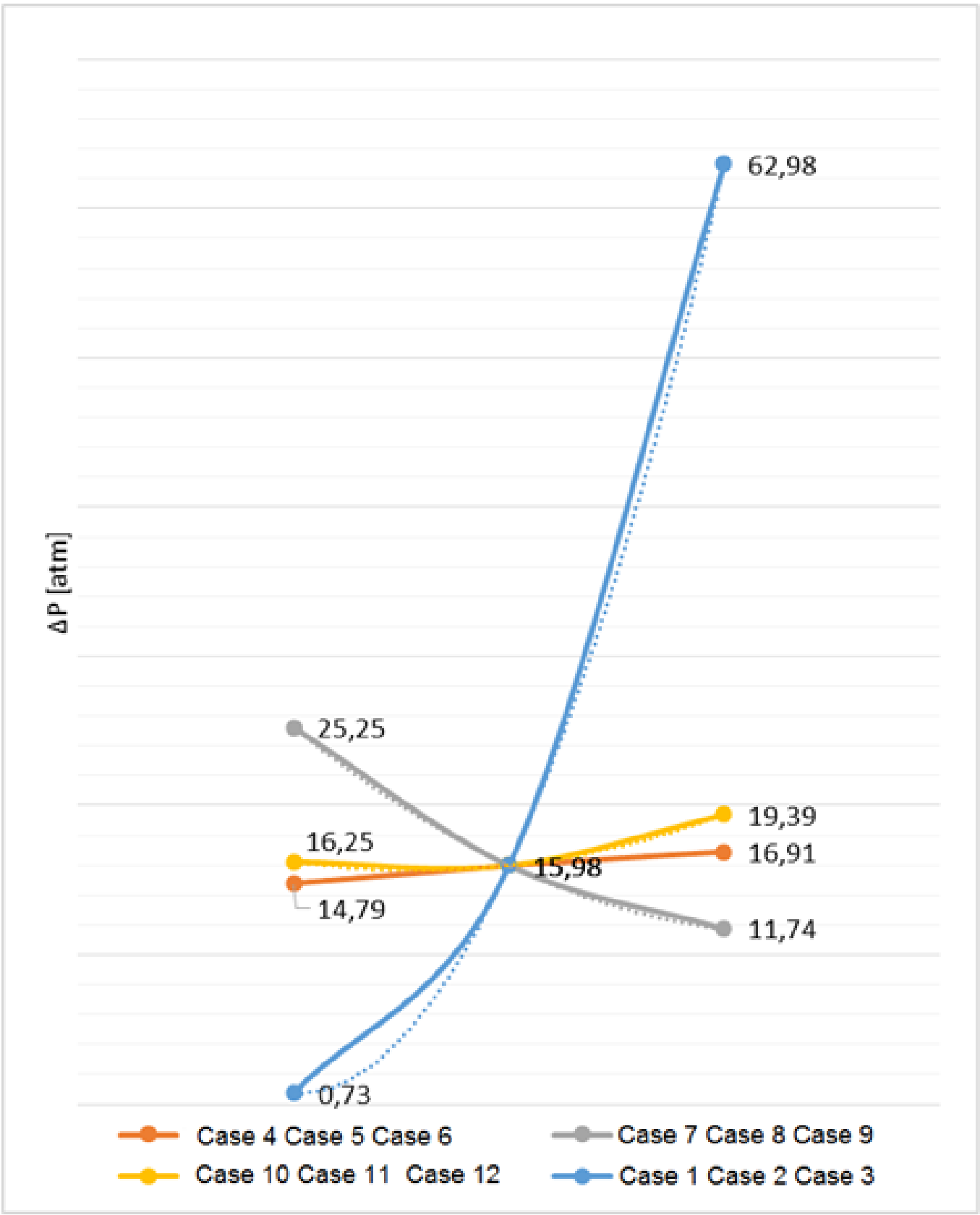

Figure 6. Representation of the total pressure drop ΔP resulted by the effects of changes on the independent variables, defined in Table 1, from left to right; each group of considered cases corresponds to a particular effect of an independent variable, according to Table 1. (Assuming a full TRIM's configuration (see Fig. 3)).

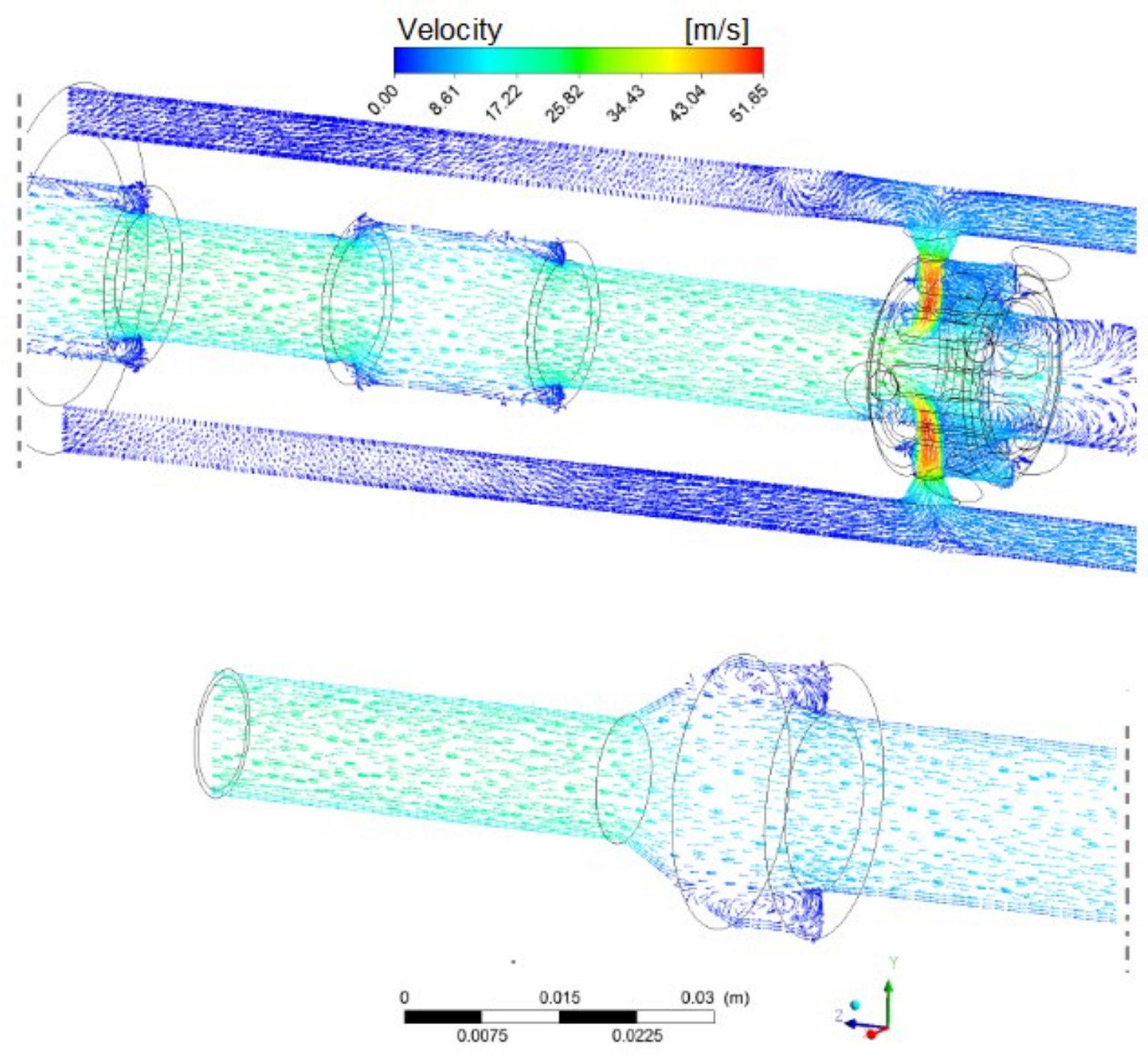

Figure 7. Normalized velocity field, represented in Plane 1, according to Fig. 5. (Assuming a full TRIM's configuration (see Fig. 3)).

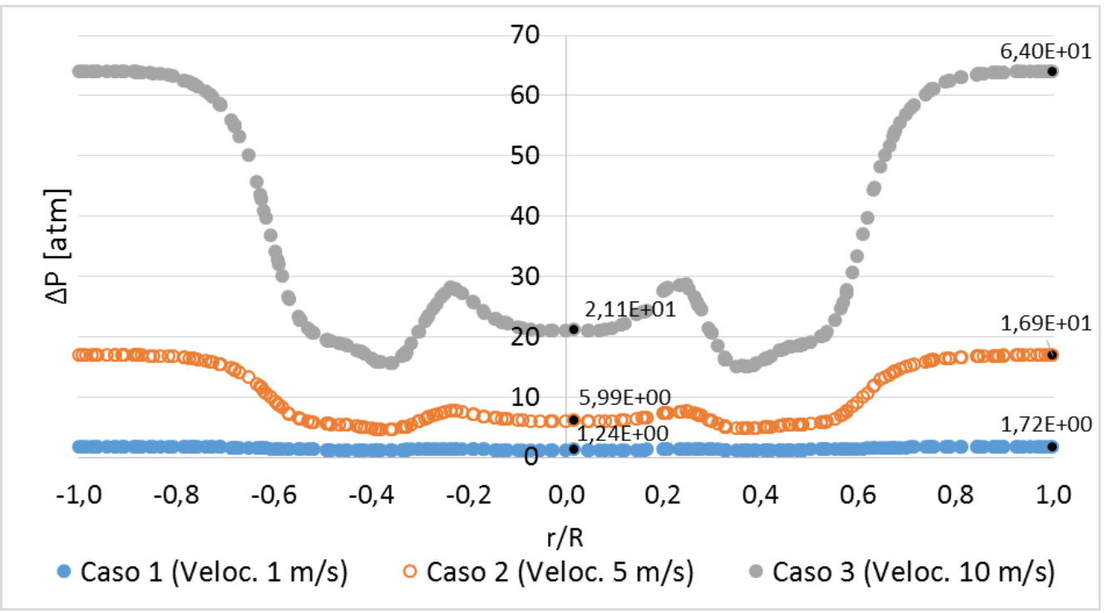

Figure 8. Effect of the variable "Veloc." in the pressure profiles in a straight-line segment (Line 1), for Cases 1, 2 and 3 (Table 1). (Assuming a full TRIM's configuration (see Fig. 3)).

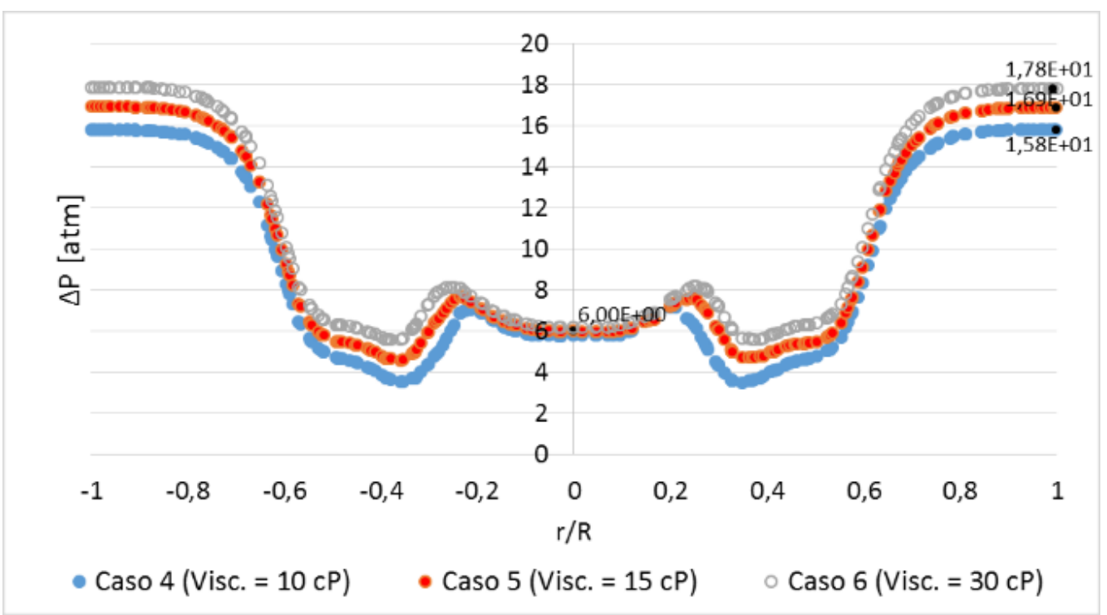

Figure 9. Effect of the variable "Visc." in the pressure profiles in a straight-line segment (Line 1), for Cases 4, 5 and 6 (Table 1). (Assuming a full TRIM's configuration (see Fig. 3)).

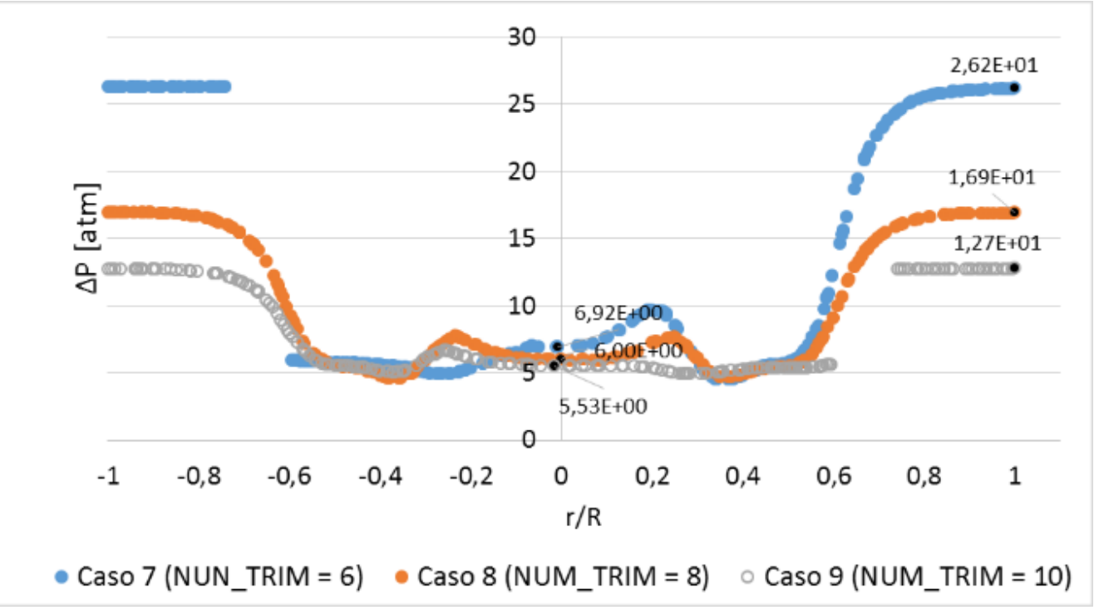

Figure 10. Effect of the variable NUM_TRIM in a pressure profiles in a straight segment (Line 1), for Cases 7, 8 and 9 (Table 1). (Assuming a full TRIM's configuration (see Fig. 3)).

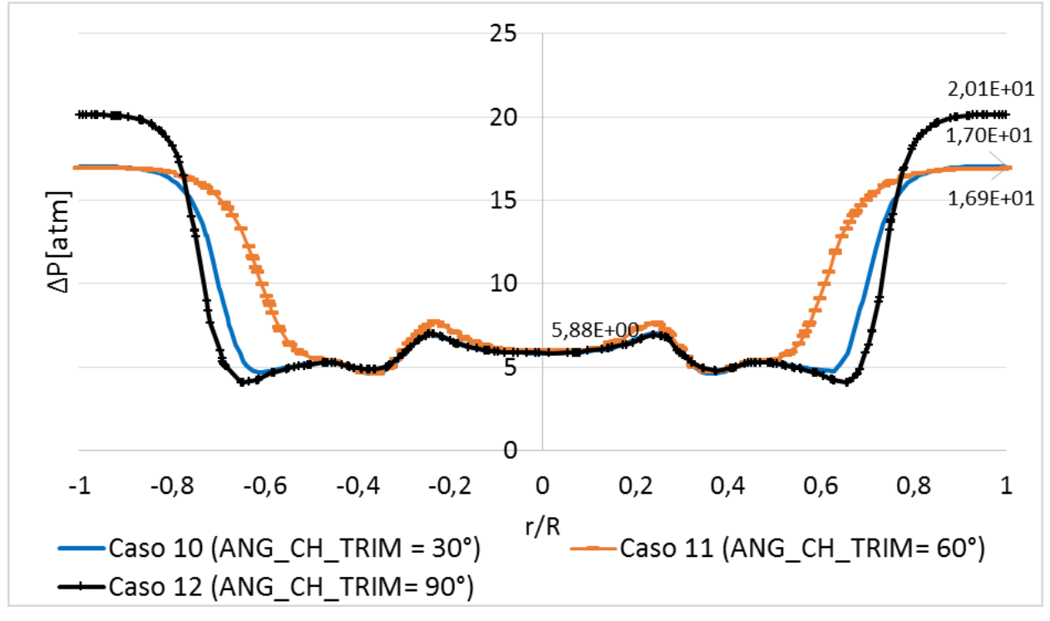

Figure 11. Effect of the variable ANG_CH_TRIM in a pressure profiles in a straight segment (Line 1), for Cases 10, 11 and 12 (Table 1). (Assuming a full TRIM's configuration (see Fig. 2)).

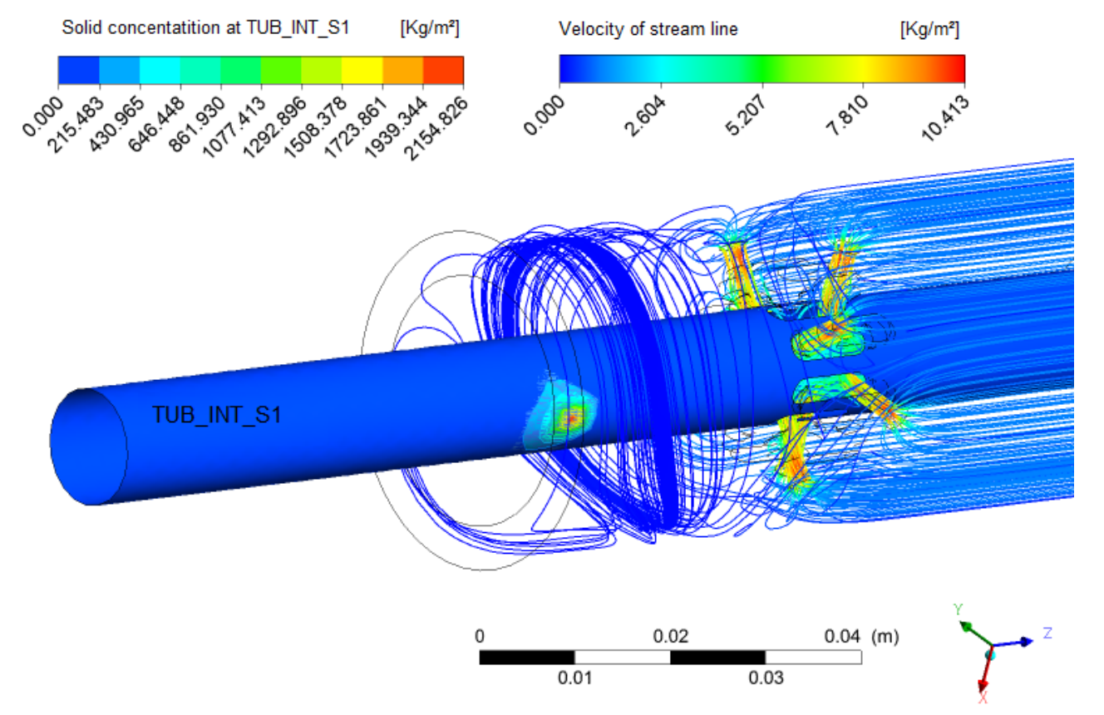

Figure 12 – Velocity streamlines and $CaCO_3$ concentration at TUB_INT_S1 for Case 13 (average velocity at ANNULAR_INLET of 1 m/s). (Assuming a simplified TRIM's configuration (see Fig. 3)).

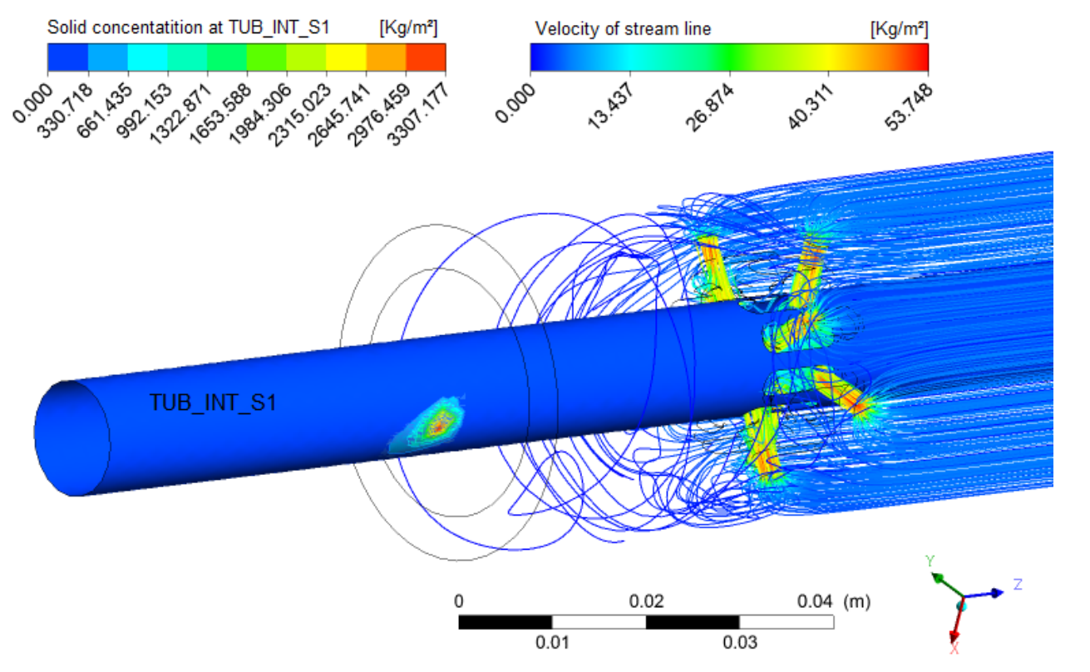

Figure 13 – Velocity streamlines and $CaCO_3$ concentration at TUB_INT_S1 for Case 14 (average velocity at ANNULAR_INLET of 5 m/s). (Assuming a simplified TRIM's configuration (see Fig. 3)).

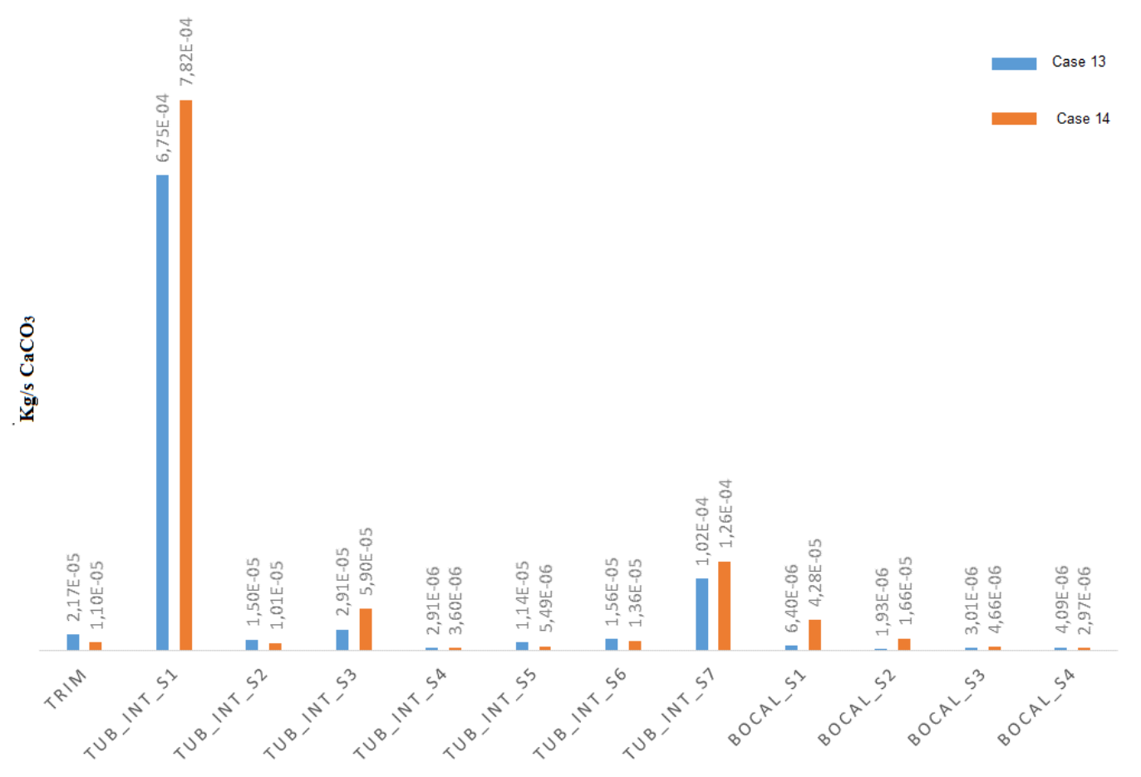

Figure 14. $CaCO_3$ adhesion rate at inners surfaces of control volume, assuming a simplified TRIM's configuration (see Fig. 3).

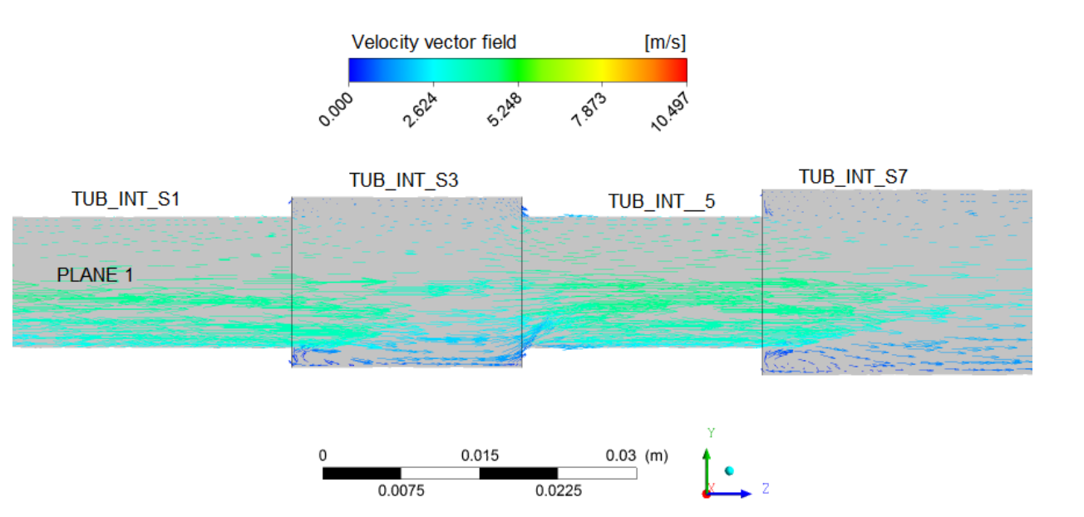

Figure 15. Normalized vector velocity field, represented in Plane 1, according to Fig. 5 , for Case 13 (average velocity at ANNULAR_INLET of 1 m/s) close to the regions of TUB_INT_S1, TUB_INT_S3, TUB_INT_S5 and TUB_INT_S7 (assuming a simplified TRIM's configuration (see Fig. 3)).

4. CONCLUSION

Through the analysis and considering the simulation of Table 1, it has been concluded that the minimization of the total pressure drop is constituted by the following conditions:

Average inlet velocity of the fluid close to 1 m/s, viscosity tending to 1 cP, number of connections in the TRIM equal to 10, and chamfer angulation around 60° in the TRIM's entrance.

The DPM simulation allows identifying features of the scaling generated by the $CaCO_3$ transported by the continuous phase. A close relationship between the flow rate and the inners control volume region with the scaling behavior was observed. In general, in regions with higher fouling rates (TUB_INT_S1, TUB_INT_S3, and TUB_INT_S7), such rate are directly proportional to the flow rate. However, for other regions, there are quite different effects, either direct or inversely to the intensity of the flow, especially in the low-velocity recirculation regions, but with a lower average intensity.

5. MAIN REFERENCES

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