Analysis of the shear stresses in a filling line of parental products: the role of tubing and fittings

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ANALYSIS OF THE SHEAR STRESSES IN A FILLING LINE OF PARENTAL PRODUCTS: THE ROLE OF TUBING AND FITTINGS

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Introduction and problem statement

Bioprocessing steps of parentals traditionally involve large velocity gradients. These gradients result in high shear stresses, generally believed to affect product stability. Precise modelling of unit operations is therefore necessary to quantify the sources of shear. Here, CFD analysis was applied to flow through **tubing** and **fittings** under laminar and turbulent conditions; equations were proposed to assess the average shear experienced by the product.

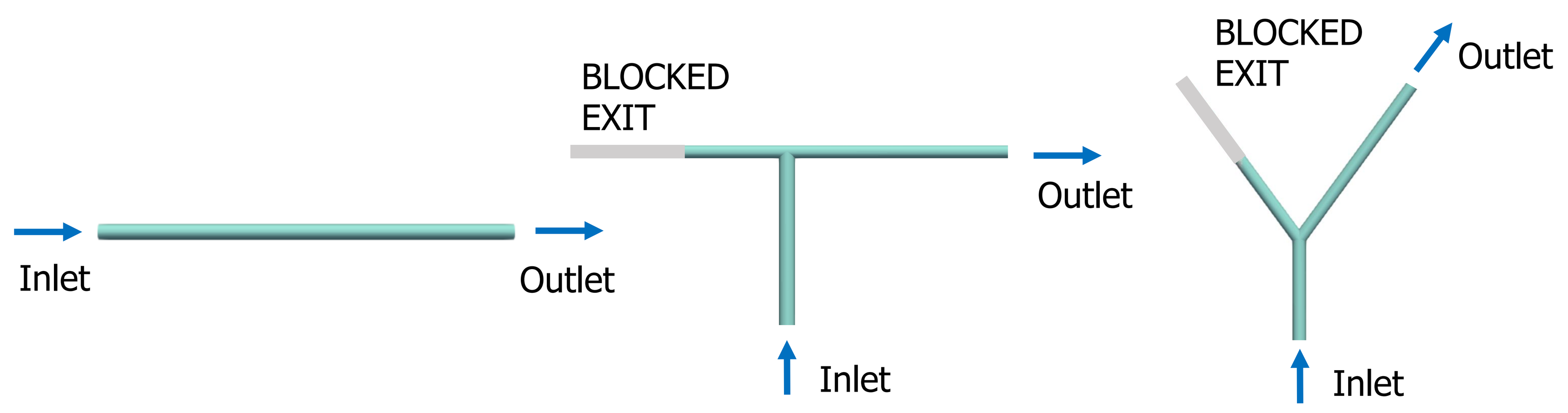

Fig.1a,b,c Geometries analyzed: straight smooth tubing, smooth Y- and T-fitting used throughout the line to sample products when needed.

When modelling matters

Scale-down approaches are necessary to characterize and control the commercial process by performing process evaluations at the laboratory level. Such analyses are not feasible or cost-prohibitive at the manufacturing unit.

COMMERCIAL → SCALE-DOWN APPROACH → LABORATORY

Definition of the proper **scaling parameter**

- Indispensible tool for process development, optimization and control.
- Representiveness is ensured between commercial and laboratory unit.
- Small product quantity employed.

From geometry to shear distribution

Case study: flow through smooth tubing. Fluid with water-like properties. Laminar regime.

Geometry grid: Case study is developed by collecting relevant geometrical information from suppliers. Appropriate mesh is built in the CFD solver.

CFD simulations: CFD solver is used to solve the Navier-Stokes equations and the fluid dynamics.

Post processing: Particles are tracked through their trajectories across the geometry and local properties are detected.

Mathematical modeling: Shear stress distribution models are then proposed and numerically validated.

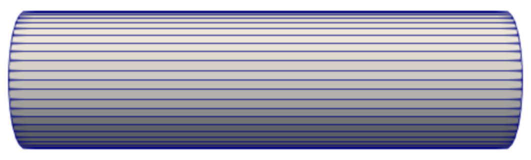

Fig.2 Grid of the geometry obtained by the CFD mesher.

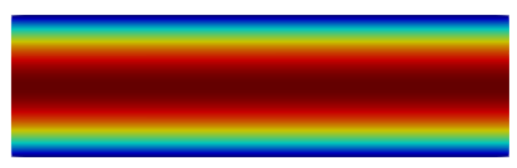

Fig.3 Velocity contour plots in the cross-sectional area of the geometry. Follow the color scale from blue (low velocity) to dark red (high velocity).

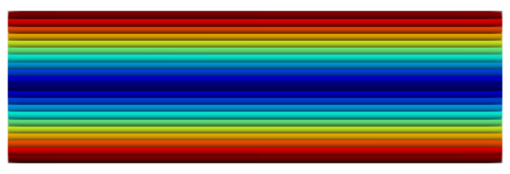

Fig.4 Shear stresses characteristic of defined particles' trajectories. Follow the color scale from blue (low shear stress) to dark red (high shear stress).

$$< \sigma > = \frac{1}{Q_{tot}} \sum_i \sigma_i Q_i$$

Eq.1 Mathematical equation to find the average shear stress $< \sigma >$ by averaging the local shear σ_i, characteristic of each streamline, by its relative flowate, $\frac{Q_i}{Q_{tot}}$. This allows to account for the actual product flowing through the geometry.

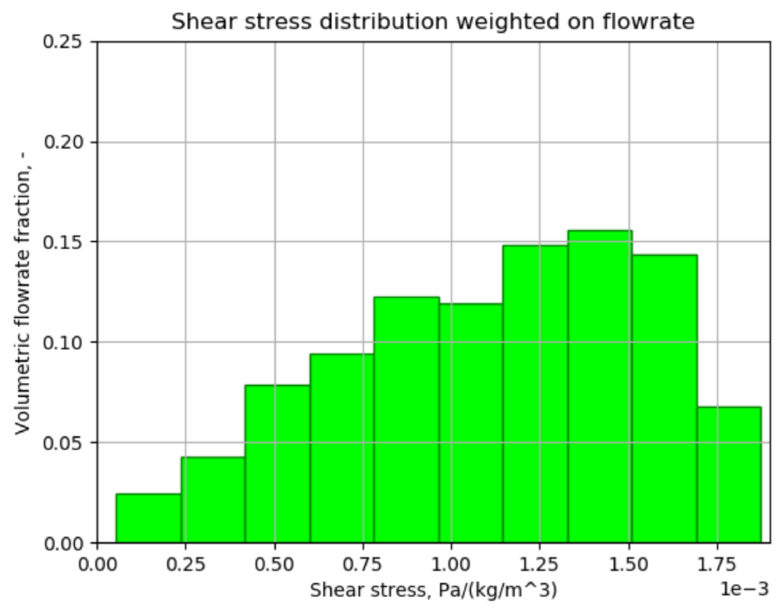

Fig.5 The highest shear stresses are experienced by small portions of the overall product.

Scale-down approach for tubing

The proposed equations enabled the identification of scale-down approaches while using the shear stress distribution as a scaling parameter. For **laminar** flow in tubing, for instance, the following equation was proposed:

SCALE-DOWN EQUATION $$\frac{u_c}{r_c} = \frac{u_l}{r_l}$$

Eq.2 Ratio between velocity (u) and radius (r) is constant between the scales (c, l).

COMMERCIAL $d_{comm} = 9.53\ mm$

LABORATORY $d_{lab} = 4.76\ mm$

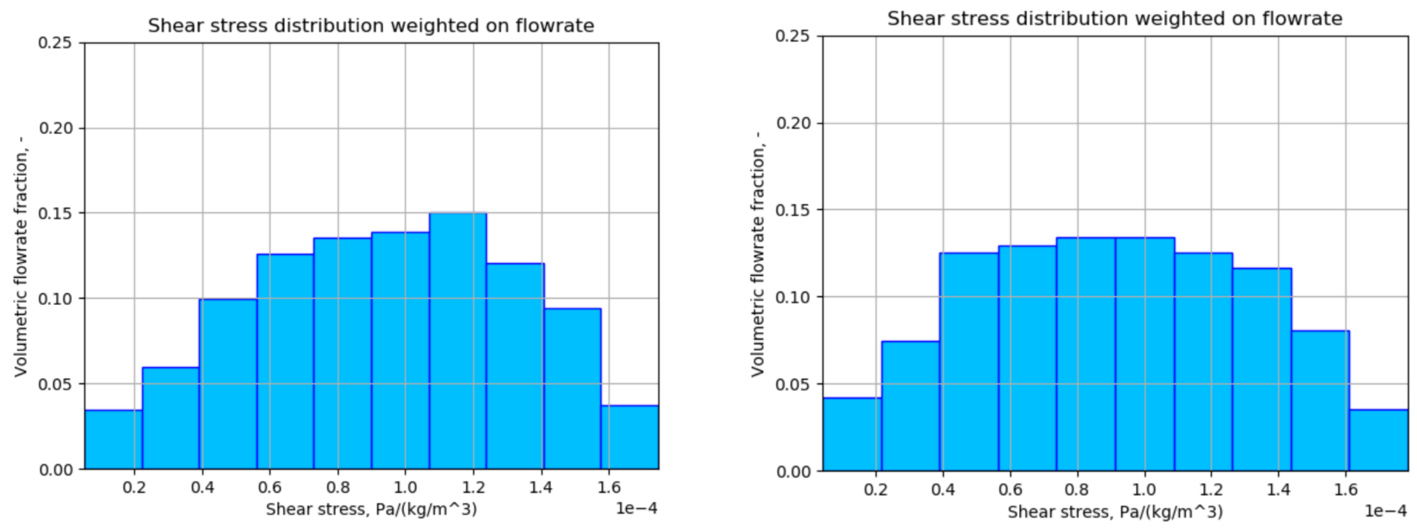

Fig.6 Results of the application of the proposed scale-down approach for laminar flow. In the laboratory, while the tubing diameter is decreased to lower the product consumption, the shear stress distribution does not change.

Conclusions and perspectives

A new approach has been proposed for the estimation of the shear stress distribution exerted on the product when flowing through tubing and fittings.

Scale-down approaches were identified to pass from commercial to laboratory unit.

The next step will consist of performing experiments to assess the effect of such shear distribution on product's stability.

Conflict of interest
Bernadette Scutellà, Marco Bellini and Erwan Bourlés are employees of the GSK group of companies. Camilla Moino is holding a Doctorate studentship and collaborates with GSK as part of her PhD.

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