Numerical Analysis of Entry Length in Cleaning Test Rig

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Introduction: An efficient cleaning process in manufacturing industry should be done with minimum cost and time. With this aim, an upgrade to an existing cleaning rig (Figure 1) at the Universiti Putra Malaysia, consist of a rectangular flow channel with a test section to monitor the cleaning process was conceptually designed to monitor cleaning process of fat-based fouling. The COMSOL Multiphysics 5.1 was used to test the proposed channel designs: one without settler and another with settler in the rectangular channel assembly as shown in Figure 2 & 3.

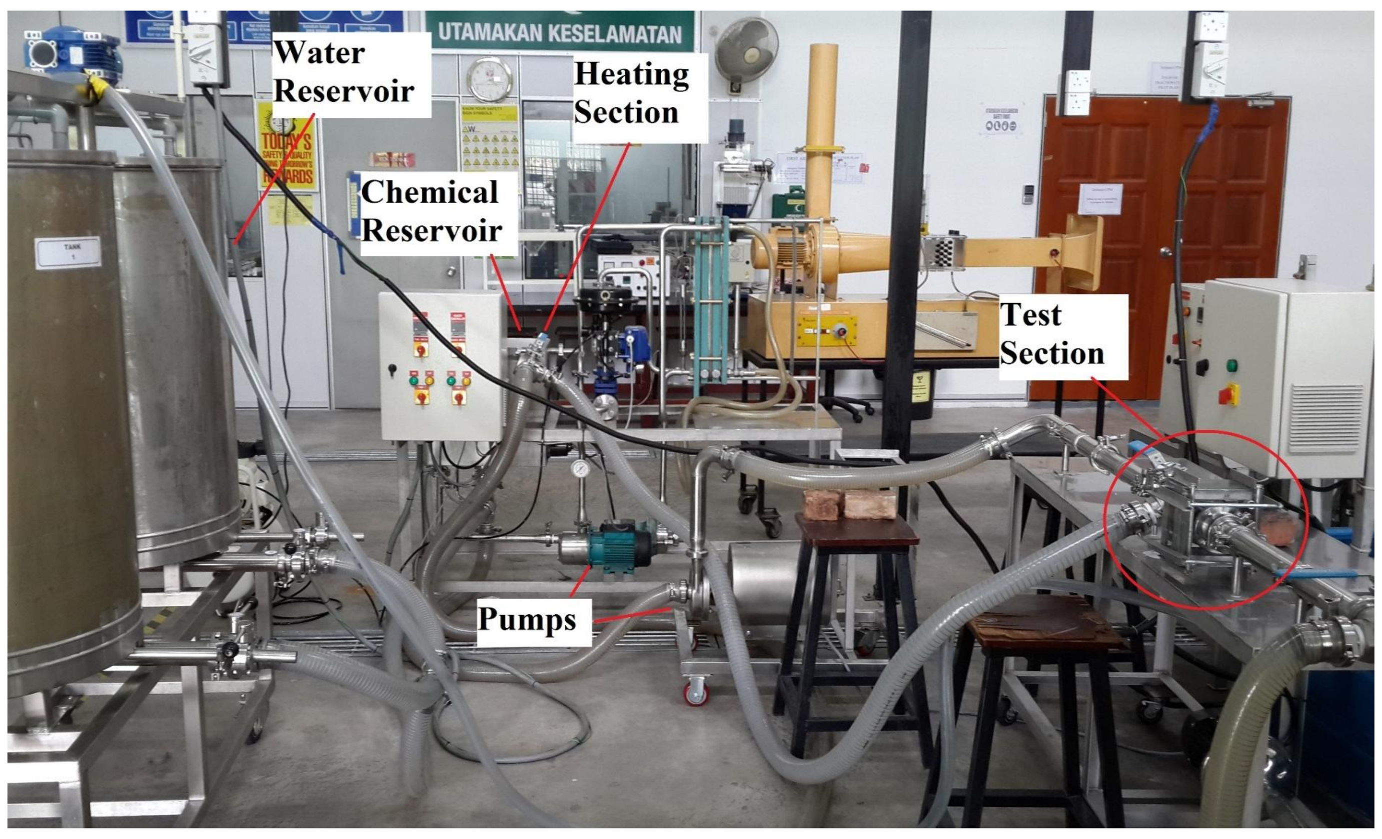

Figure 1. UPM Lab-scale Cleaning Rig

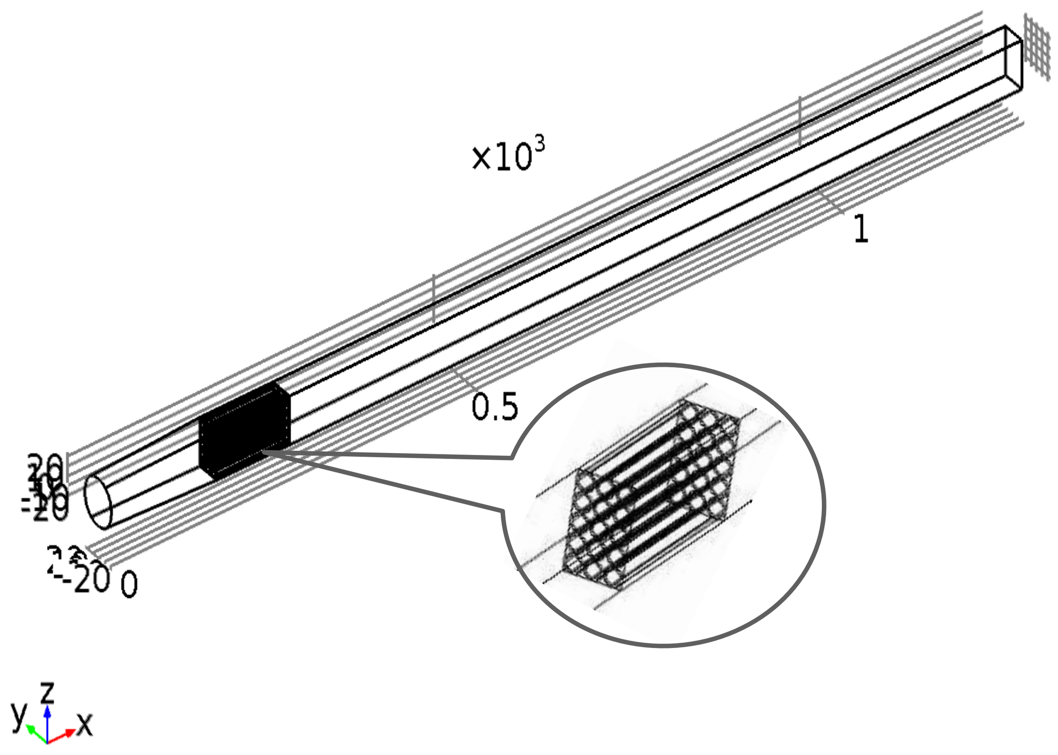

Figure 2. Channel design with settler

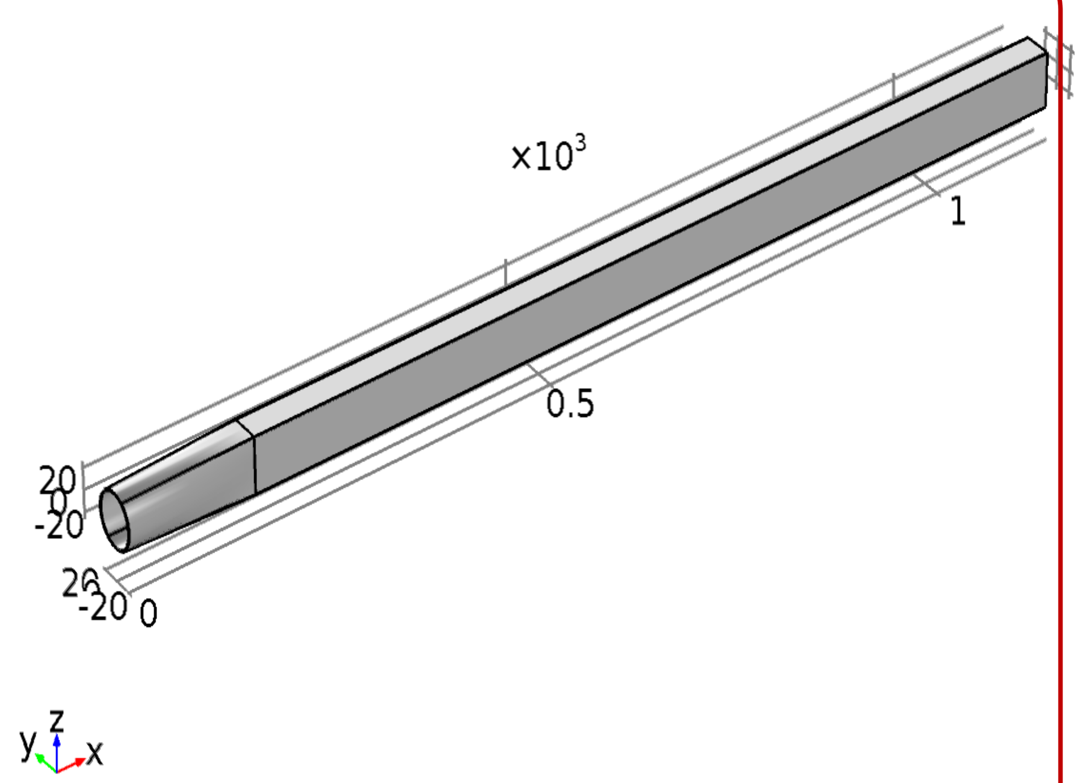

Figure 3. Channel design without settler

Computational Methods: Our main objectives are to visualize fluid flow pattern in the channel and to predict the best entry length, L_e. Fluid flow pattern changes from circular pipes (as inlet) to rectangular channel (as outlet) causing disturbance in velocity profile. For both designs, stability of velocity magnitude in flow along the channels signify the region of fully developed flow which is appropriate for the test section's location in the assembly.

L_e Prediction:

Reynolds Number	Hydraulic Diameter (rectangular duct)	Entry Length
$Re = \frac{\rho V D_h}{\mu}$	$D_h = \frac{4(W \times H)}{2(W+H)} = \frac{2WH}{W+H}$	$L_{e,\ turbulent} = 1.359Re^{1/4}$

COMSOL Simulation:

COMSOL Modules: CAD Import Module, Multiphysics & CFD Module
Turbulence Model: Algebraic yPlus
Fluid : Water
Reynolds-Averaged Navier-Stoke (RANS) equation: $\rho \frac{\partial U}{\partial t} + \rho U \cdot \nabla U + \nabla \cdot \overline{(\rho u' \otimes u')} = -\nabla P + \nabla \cdot \mu (\nabla U + (\nabla U)^T) + F$; $\rho \nabla \cdot U = 0$
Boundary Conditions: Wall: No-slip condition (u = 0) , Inlet: Velocity ($u = -U_o$), Outlet: Pressure ($\widehat{p_0} \leq p_0$)
Input Parameters: Inlet velocity (0.5m/s, 1.0m/s, 1.5 m/s)

Results:

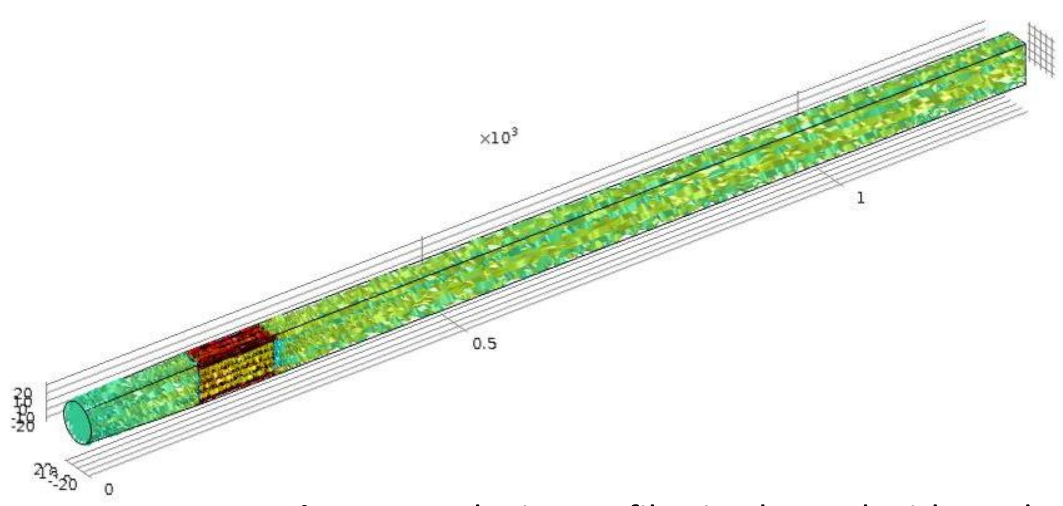

Figure 4. Velocity profiles in channel with settler at inlet velocity=1.5 m/s

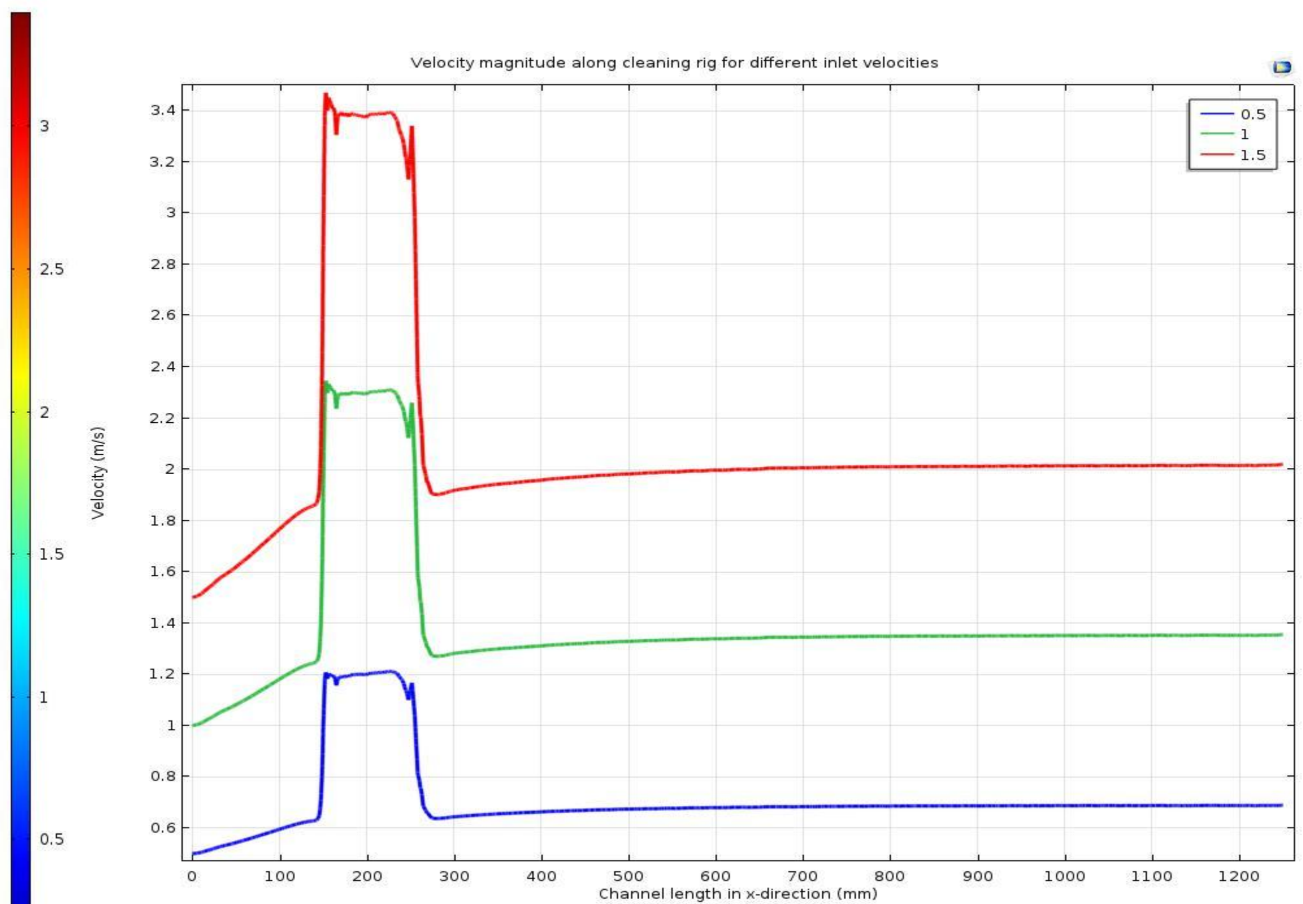

Figure 5. Velocity profiles in mid channel with settler at all inlet velocity (L_e for 1.5m/s = 800mm)

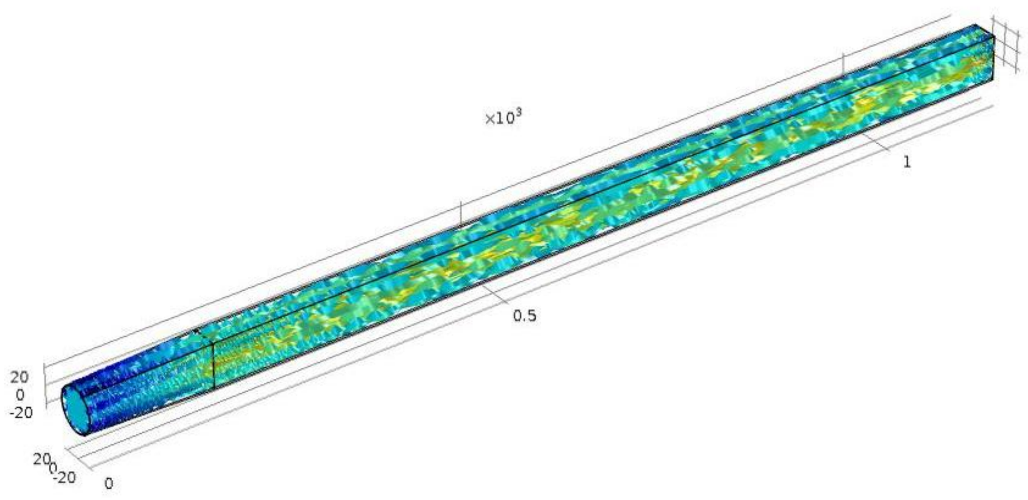

Figure 6. Velocity profiles in mid channel without settler at inlet velocity=1.5 m/s

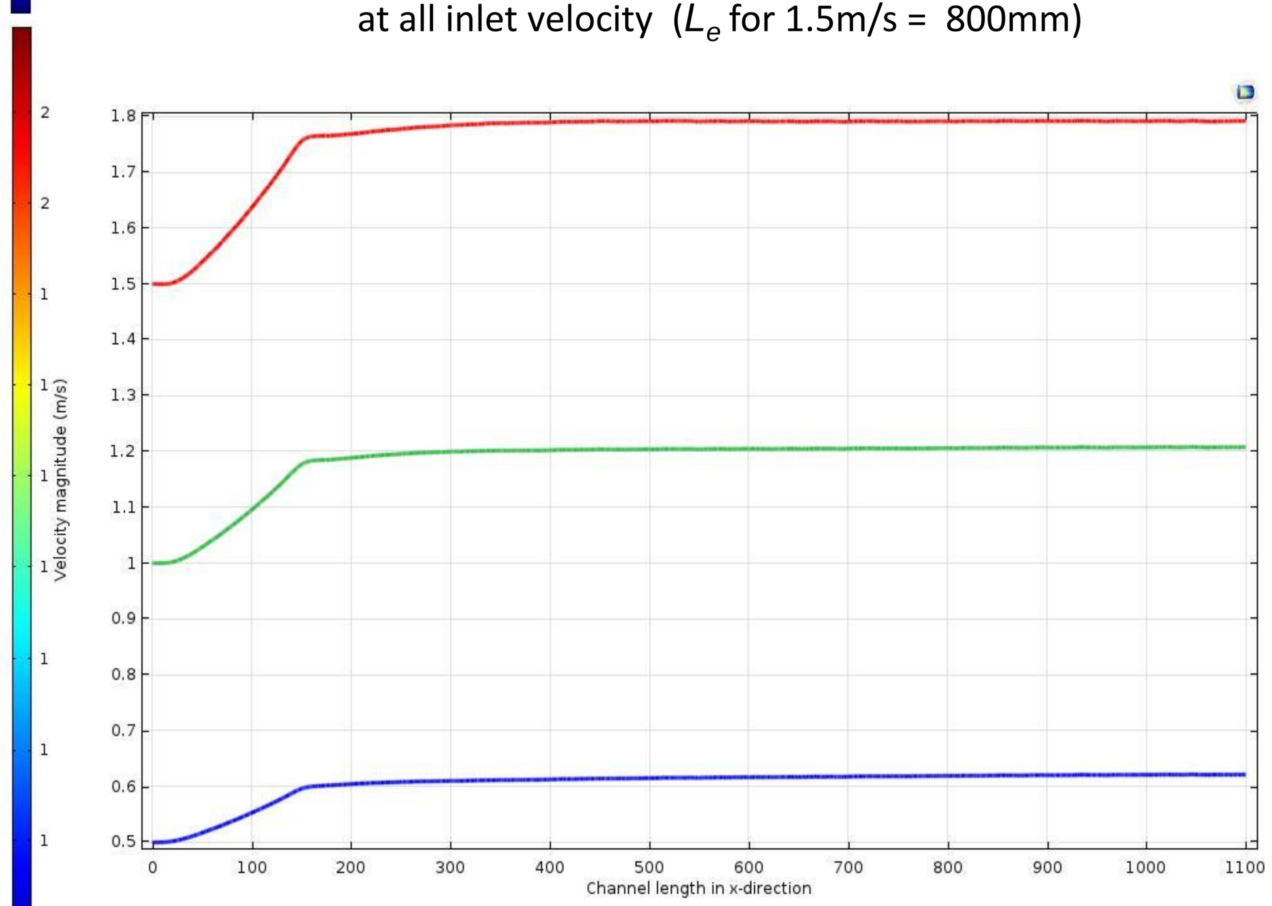

Figure 7. Velocity profiles in mid channel without settler at all inlet velocity (L_e for 1.5m/s= 1000mm)

Conclusions:

- The new designs for the cleaning rig has been validated numerically using the COMSOL Multiphysics.
- From the flow profiles, the L_e value for both designs were successfully determined which then used to finalize the best design.
- L_e for channel with settler = 800mm & L_e for channel without settler = 1000mm.
- The simulation results are critical input in order to proceed with the fabrication of the upgraded cleaning rig.

References:

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2. N.I. Khalid, N. Nordin et al, Design of a Test Rig for Cleaning Studies and Evaluation of Laboratory-Scale Experiments Using Pink Guava Puree as a Fouling Deposit Model, Journal of Food Process Engineering, Online publication: doi: 10.1111/jfpe.12188, (2015)
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