Associating Fundamentals of Momentum Transfer with HYSIM Simulator in Chemical Engineering

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Abstract - *Usually the simulators are used to develop skills in the area of process simulation. The idea of this article is show the commercial simulator HYSIM as a good tool to make the learning of basic concepts of undergraduates disciplines of Chemical Engineering, in this case fundamentals of Momentum Transfer, more dynamic and "tasteful" for the students.*

Introduction

The program REENGE is an educational branch of Brazilian Program for Engineering Development (PRODENGE). At Chemical Engineering College of Campinas State University (UNCAMP), this program aims an undergraduate course improvement through the most common software used by Chemical Industries, e.g. MATLAB, a powerful mathematic tool; HYSIM, a commercial process simulator; AutoCAD, a technical drawing software. This program assists the creation of cases which will illustrate the concepts developed in Chemical Engineering undergraduate course and shows to the students the available tools in Chemical Industries. To extend the benefits of REENGE's work, some of the result's obtained will be available in World Wild Web.

Particularly in this work attention is given to the development of an innovative methodology either to teach or to reinforce the main concepts on the fundamentals of Momentum Transfer. The idea of this work is to apply HYSIM as tool to make the learning of basic concepts procedure more dynamic and "tasteful" for the students.

Head Loss Due to Fitting Apparatus

In the undergraduates laboratories a Head Loss Due to Fitting Apparatus is available, which consist on a set of pipes with many kinds of fitting. The pressure loss (Δp) in each fitting is measured by differential manometers in "U" and volumetric flow by orifice plate. Illustration 1 show the apparatus sketch.

Fittings are tubing accessories that can connect pipes, flow control, change flow direction, etc. However, because they cause flow disturbance, mechanical energy is converted in thermal and sonorous energy (head loss).

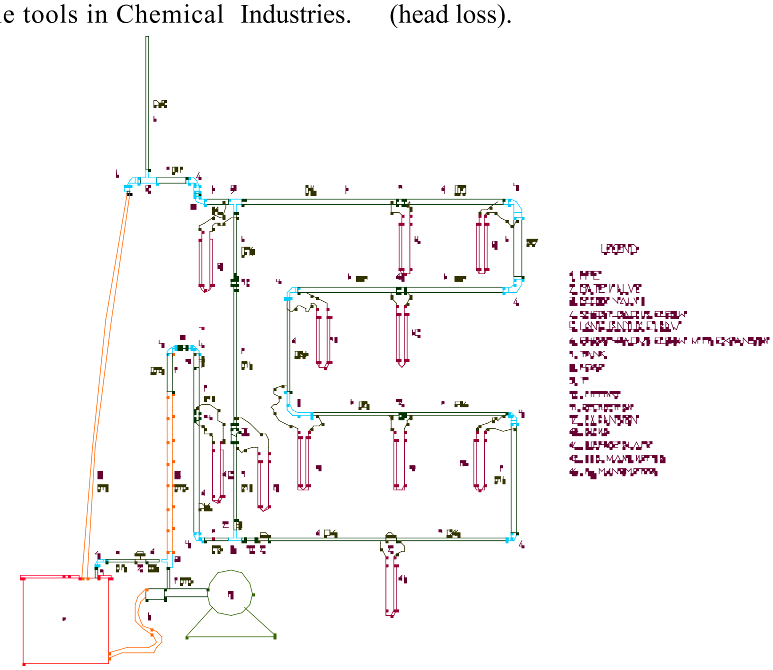

Figure 1 - Head Loss Due to Fitting Apparatus Sketch

Figure 1 shows the different fittings available in the apparatus (gate valve, globe valve, Ts, short-radius 90^o elbow, long-radius 90^o elbow, reduction, expansion).

The objective of the present work was to simulate the Head Loss Due to Fitting Apparatus though the commercial simulator HYSIM. This system will be used by students to simulate the operational conditions previously experienced with the apparatus.The fittings could be simulated trough HYSIM operation called “pipe-segment” and the definition of equivalent length (L_{eq}). L_{eq} is the tube length with the same diameter in which the fitting is available that gives a head loss equal to the fitting.

Equivalent length values are easily find in literature ([1] and [2]).

But the manometers and orifice plate could not be simulated in this manner. Meanwhile, through a HYSIM feature called “Calculator” new operations could be programmed. With HYSIM Calculator the operations Orifice Plate and Manometers were developed. Also for these operations a graphical interface and new icons on process flow diagram (PFD) were created to better simulate the apparatus, as illustrated in figure 2.

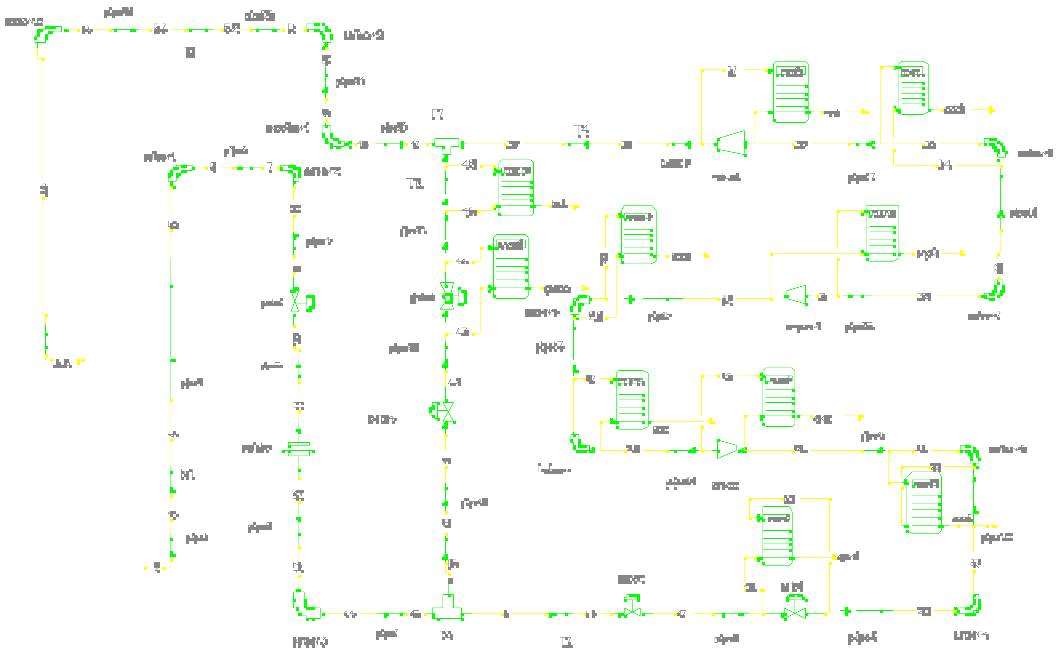

Figure 2 – HYSIM Process Flow Diagram

HYSIM usually considers the ideal situation in which the flow is fully developed. However, in the Head Loss Due to Fitting Apparatus there is not enough length between two fittings to overcome the entrance length so the fully developed flow is not obtained.

The flow is fully developed when the velocity profile inside the tube does not vary with its length, as presented in figure 3. The distance downstream from the fitting to where flow becomes fully developed is called entrance length (L_e). For the turbulent flow, the entrance length is near 50 diameters downstream the fitting and for the laminar L_e is expressed by Langhaar's equation [2] which is presented bellow.

$$\frac{Lentrada}{D} = 0,0575 * Re \qquad (1)$$

Figure 3 – Entrance Length

Simulations

Ideal Case

The first step was the simulation of a ideal circuit which considers that the condition of steady -state and fully developed flow were satisfied. To satisfy this, pipes not presented in the apparatus were added in the simulation, to achieve the fully developed flow, and L_{eq} values from literature, [1] and [2], were used.

Actual Case

To represent the condition experienced with the Head Loss Apparatus, a new simulation was created to better represent the experimental data. Using experimental values of manometric deflection and volumetric flow, tubes length which better represent the head loss in the fitting could be determined.

Results

Using the manometric deflection, the head loss was calculated through the modified Bernoulli equation.

$$h_L = (y_1 - y_2) + \frac{(P_1 - P_2)}{\rho . g} + \quad (2)$$

Figures 4 and 5 shows the Head Loss versus Volumetric Flow graphics. This plots compares the experimental data with the simulated data for each fitting in the apparatus.

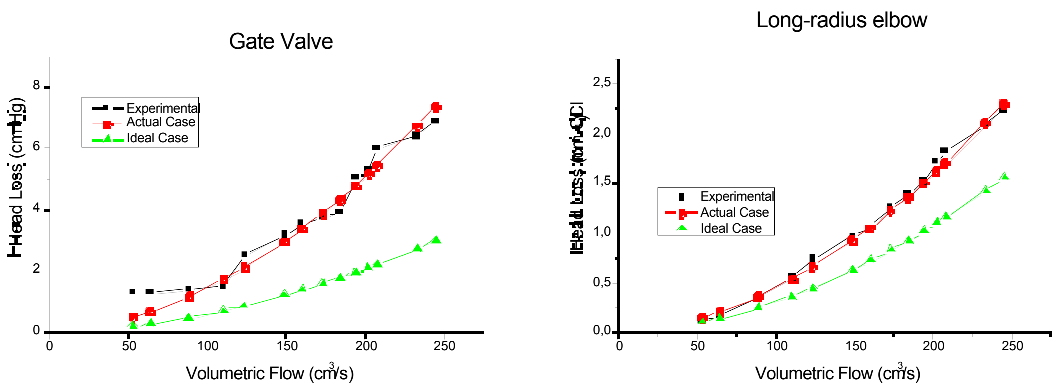

figure 4 – Head Loss x Volumetric Flow: Gate Valve; Long-Radius Elbow

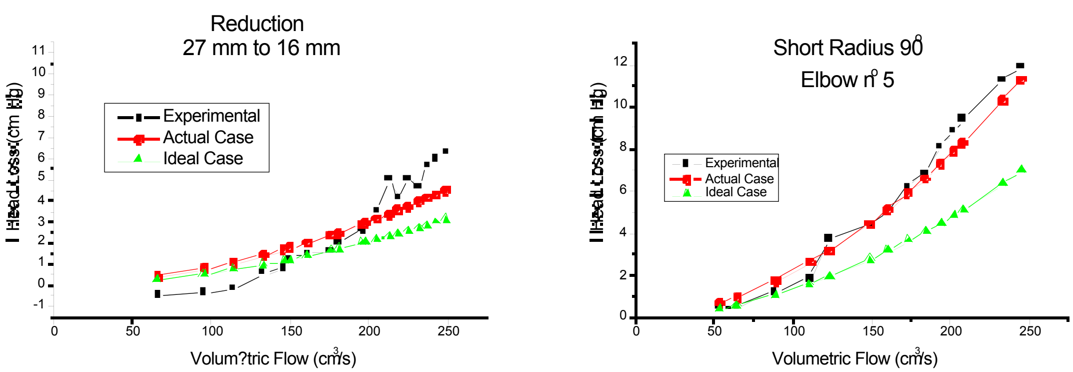

figure 5 – Head Loss x Volumetric Flow: Reduction 27/16; Short Radius 90^o Elbow

Analyzing the graphs, the undergraduates students will face differences in the results observed in the apparatus and those ones simulated though HYSIM. This will instigate them to handle the fundamentals of momentum transfer to conclude that differences in the results are due to the non-developed flow occurred in the apparatus. Thus, the head loss obtained in the apparatus and in the real simulation is greater then the effective head loss (ideal simulation), which only can be measured when flow is fully developed. To be able to achieve this conclusions the undergraduates need to know well the basic concepts involved in fundamentals of momentum transfer.

Nomenclature

The symbols and suffix used in this article are defined below:

H_L - Head Loss (cm of manometric fluid)

y_i - Elevation (cm)
P - Pressure (dyna/cm^2)
ρ - Density (g/cm^3)
v - Velocity (cm/s)
g - Gravity acceleration (cm/s^2)
L_{eq} - Equivalent Length (mm)
L_e - Entrance Length (mm)
Subscript 1 - Upstream
Subscript 2 - Downstream

Conclusion

The two simulations have illustrated the fully developed and the non-developed flow and concurrently the students will be able to know basic features of this powerful simulation tool, HYSIM. In order to assist the students a text containing the main concepts and the governing equations was also prepared. This text is accessible in World Wild Web.

References

1) Foust, A.S. et al., *Princípios das Operações Unitárias.*, 2.ed. Rio de Janeiro, Guanabara 2, 1982.
2) Welty, R.J.; Wicks, C.E.; Wilson, R.E., *Fundamental of Momentum, Heat and Mass Transfer.*, 3.ed. Singapoure, John Willey & Sons, 1984.