Case Study #8: Flushing Efficiency Enhancement

Challenges:

- Model water and air interactions as well as solid content during flushing

Results:

- Developed consistent methodology for toilet flushing
- Validated model by conducting sensitivity studies

Summary

To reduce the amount of water used for toilet flushing while still maintaining flushing efficiency is crucial for the next generation toilet. MindMesh Inc. developed multiphase Computational Fluid Dynamics (CFD) models to assist toilet design improvement. We used Tdyn, a state-of-the-art CFD software platform, to perform high-fidelity flushing flow analysis and Fluid-Structure Interaction (FSI) analysis. We designed various tests to improve the understanding of multiphase flow physics. These consisted of simple jet case, geometry/mesh (Fig.1), velocity c ontour (Fig.2), and velocity vector (Fig.3). CFD analysis has been proven accurate through these types of sensitivity studies. Figures 4-6 show the level of detail that can be obtained from this analysis, which is very useful for design optimization.

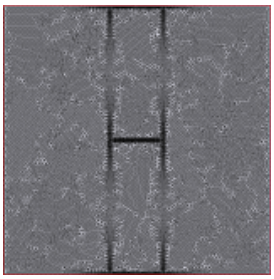

Fig. 1: *Jet mesh*

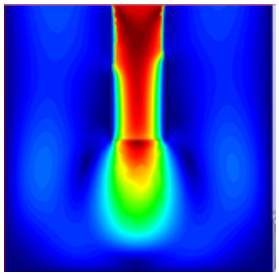

Fig.2: *Jet velocity contour*

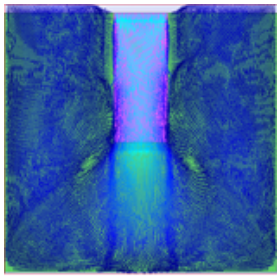

Fig.3: *Jet velocity vector*

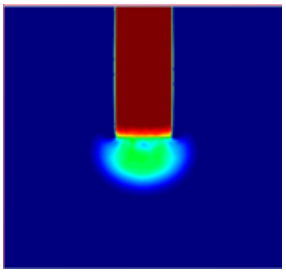

Fig.4: *Jet interface: 0.05s*

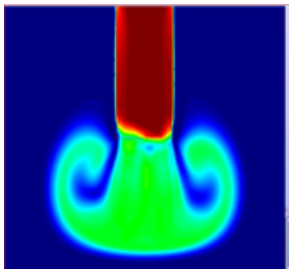

Fig.5: *Jet interface: 0.35s*

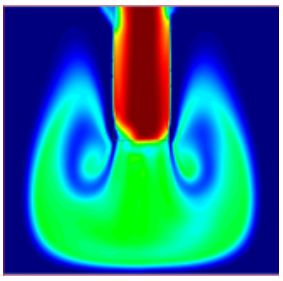

Fig.6: *Jet interface: 0.55s*

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About the Client:

This client is the most recognized name in the toilet care market, being the number one brand in the world. Their products are not only top quality, but easy for consumers to use and used by professional plumbers everywhere. As they continue to expand, this client ensures that they stay at the forefront of their market and are constantly taking the necessary steps to develop the technology needed to offer the best products.

Challenge:

The purpose of toilet multiphase CFD analysis is to gain knowledge and interpret the data gathered from sensitivity studies. This information is used to evaluate and develop understanding and methods to predict flushing efficiency of toilets. Our eventual goals are to optimize toilet design, improve upon flushing efficiency and improve overall toilet usage. There are multiple challenges of modeling toilet flushing, the biggest being toilet design, modeling water and air interactions and modeling solid content during flushing, all of which require a Multiphysics type of analysis.

How Did We Help?

Toilet flushing is a very complex process involving multiphase flow, jet flow, and fluid-structure interaction. To improve the flushing efficiency through tests is not a trivial task due to lack of detailed flow information. In addition, an optimal design is very demanding to reduce water usage while the geometry and physics complexities (Fig. 7 and 8) did lag this process.

The CFD models we developed were used to achieve and interpret detailed flow information (Figs. 9-11), and then compared to test data to provide multiple design options for further testing. We developed a series of numerical methods to model the multiphase fluids, namely air and water. We validated those with known results as illustrated in Figures 1-6. We then introduced solids into the model to get a better idea of how multiphase with solids would behave. Once all the small scale validation was completed, we used the knowledge gained from these to model the flushing of the toilet.

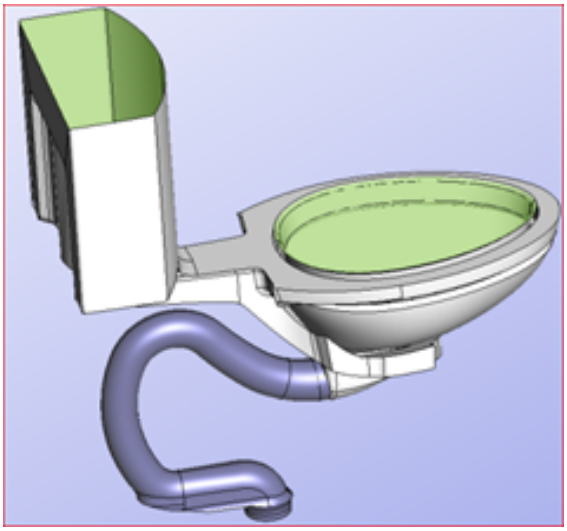

Fig. 7: *Toilet geometry*

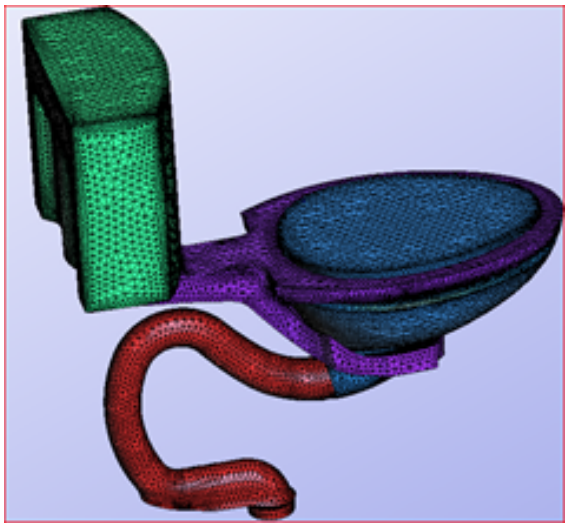

Fig.8: *Toilet model mesh*

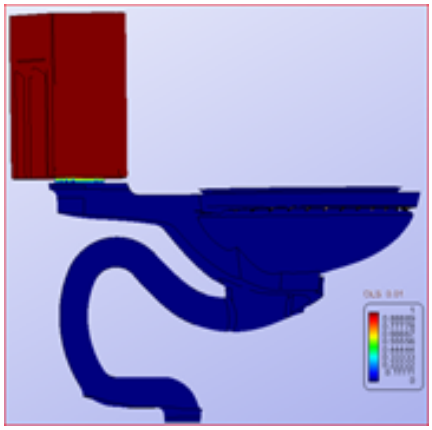

Fig. 9: *Water Fraction: 0.1s*

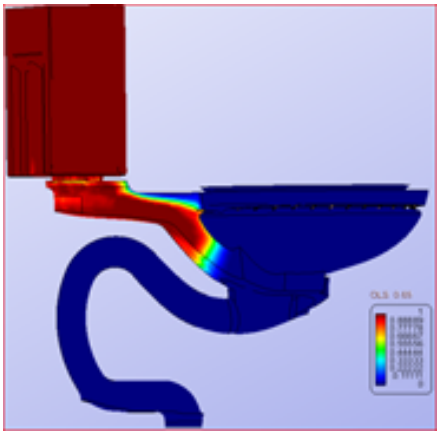

Fig. 10: *Water Fraction: 0.65s*

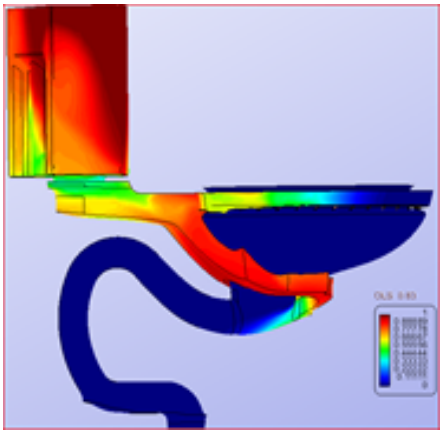

Fig. 11: *Water Fraction: 0.75s*

Results:

By developing and validating small scale models to efficiently model multiphase behavior with and without solids, we achieved the following:

- We used knowledge from these small scale tests to develop a consistent methodology for toilet flushing
- We validated the model by conducting sensitivity studies and compared that with other numerical tools
- We gathered and interpreted detailed flow information for design optimization

Value to Client:

- We developed methodology to model multiphase behavior flows that has wide application for the client
- We improved the technology for future product development and optimization of toilets and flushing efficiencies
- We reduced overall costs by advancing numerical methods, that will eventually reduce testing methods