Ultra-low NO_x Burners Get

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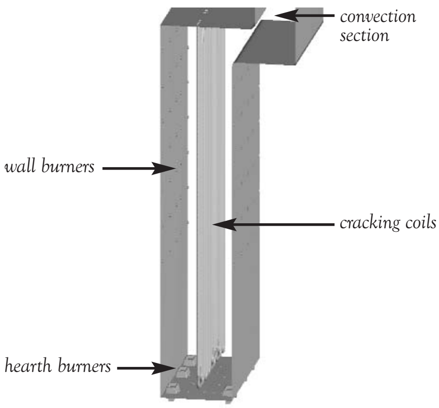
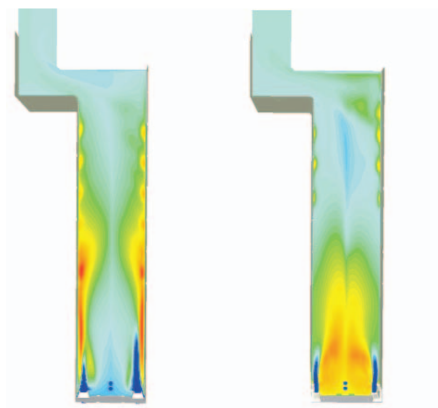
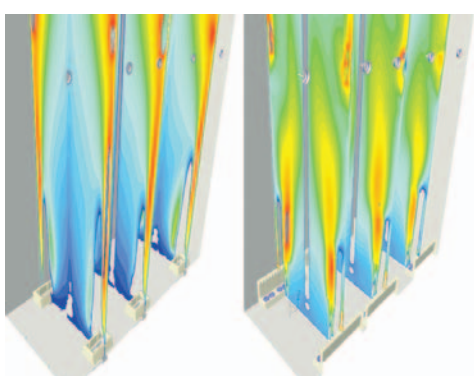


The geometry of the ethylene cracking furnace



Temperature contours in the original burner configuration (left) and the first ultra-low NO_x design (right)



Temperatures on three cross-sectional planes in the original burner configuration (left) and the improved ultra-low NO_x design (right)

ENGINEERS AND MANAGERS involved in chemical and hydrocarbon processing are keenly aware of equipment efficiency and plant productivity, and the ongoing need for improvement in these areas. In ethylene production furnaces, light hydrocarbons are cracked in tubes that are suspended in a combustion chamber. The tubes have very short residence times. The critical parameters in the operation of this furnace are the transfer of the heat of cracking to the tube side hydrocarbons, control of the tube metal temperatures for prolonged run length, and the reduction of pollutants such as NO_x to meet regulatory statutes. In the radiant section of a typical furnace, combustion heat is provided by burning fuel in hearth burners (located on the floor of the furnace and firing vertically) and in wall burners (positioned along the wall and firing radially along the wall).

The John Zink Company has developed an ultra-low NO_x burner (20 to 30 vppm) in which a portion of the fuel is premixed with all of the air in both the hearth and wall burners. The remaining fuel needed to achieve the firing rate is introduced in a staged manner to control the temperature of the combustion gases and thereby minimize the production of NO_x. This is done through staged ports located in front of the hearth tile at the furnace floor. When the introduction of this burner technology was considered for a client's ethylene production furnace, it was suspected that, when compared to the original conventional burners that generally produce straight vertical flames attached to the furnace wall, these lean premixed burners might produce shorter flames that could "roll over" at the bottom of the firebox and impinge on the tubes. The negative impact of rollover would be the creation of hot spots on the process tubes and subsequent increase in coking within the tubes and shortening of tube life.

To investigate this possibility, a realistic CFD study was conducted to compare the performance of the low NO_x and original burners. The detailed CFD models – one for each type of burner – included locally refined meshes around the burner inlet ports and process tubes. Combustion was simulated on the firebox side to provide the heat generation. A reacting model for the hydrocarbon cracking that occurs inside the tubes was also included, as were the effects of turbulence and radiation. Overall, there was sufficient detail to accurately reflect the heat absorption and thus provide realistic tube heat fluxes and coil metal temperatures. The models contained between two and five

Cracking

million computational cells depending on the type of burner modeled, and they required up to a week's worth of CPU time on a high speed computer cluster.

The initial simulations compared the heater with the original burners to the heater with the new burners where the new burners were simply located at the same position as the original burners. The results of this study indicated that, while the original burner design provided straight flames, the new low NO_x configuration resulted in flames that impinged on the tube surfaces.

Based on these results, an optimization study using CFD was done to develop design modifications that would allow the ultra-low NO_x burner to perform acceptably in the heater. These modifications included redirecting the angle of the fuel that was being injected through the ports in front of the new burners and relocating the burners on the furnace floor to provide lateral spacing into which the combusting gas could expand, thereby reducing the tendency for the flames to roll into the tubes. The modifications served to straighten the flames, making them more in line with those of the original burners. While the new design produces more diffuse flames than the original burner design, it is much improved from the first ultra-low NO_x design.

The new burner configuration, optimized by CFD, has been installed in the client's furnace. Flame quality and run length have been excellent and low NO_x operation has been experienced. The start-up was smooth and downtime was minimal. ■

Acknowledgement:

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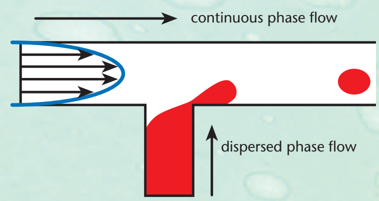
Controlling Droplet Size Distribution in Emulsions

By L. Srinivasa Mohan, Fluent India, and Ahmad Haidari and Aniruddha Mukopadhyay, Fluent Inc.

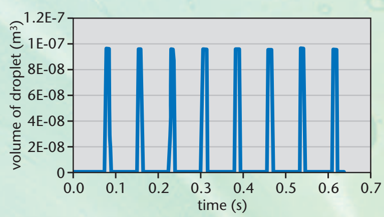
Emulsions are an important class of materials produced and handled by the chemical, food, pharmaceutical, and cosmetic industries. They consist of two immiscible liquids, one dispersed in the other. The properties of an emulsion are based on the droplet size distribution (DSD) of the dispersed phase. Because they are often thermodynamically metastable, there is a persistent threat that the texture of the emulsion will be altered during the course of preparation or packaging, or during the subsequent shelf life. Many processes over widely varying length scales could cause the DSD to change, and it is important that they be well understood so that the emulsion quality can be maintained.

For an ongoing project at Fluent, several aspects of droplet behavior have been studied using the volume of fluid (VOF) model. Some of the results have been compared to experiments that were carried out on microfluidic devices, where a precise droplet size distribution could be generated. For example, the generation of droplets at a T-junction using two streams of immiscible liquids has been simulated. Droplets of uniform size were rapidly and reproducibly produced at the junction as a result of the surface tension and the shearing motion of the fluid in the main channel, in agreement with measurements.

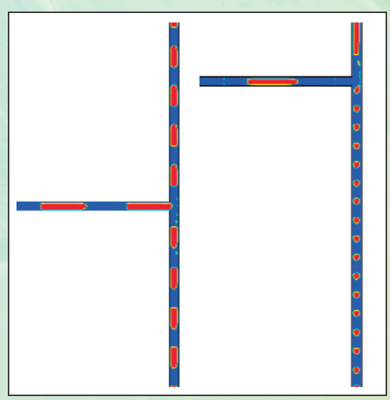
In another study, the geometrically mediated breakup of droplets in a microfluidic device [2] was simulated. By changing the length of the arms of the T-junctions, the droplet can be split into daughter droplets of unequal size. By using a network of asymmetric T-junctions, emulsions of a given DSD can be produced. Both 2D and 3D simulations matched the qualitative and quantitative aspects of the experiments, such as the size of the daughter droplets for a given T-junction and the critical parameters required for droplet breakup as a function of capillary number. ■



Schematic of the experimental setup [1]



Volume of droplets produced at the T as a function of time



Droplet breakup at a symmetric (left) and an asymmetric (right) T-junction

References

1 Nisisako, T., Torri, T. and Higuchi, T.: Lab Chip. Vol 2, no 1. pp 24-26, 2002.

2 Link, D.R., Anna, S.L., Weitz, D.A. and Stone, H.A.: Phy. Rev. Lett. Vol. 92, pp 1178-1180, 2004.