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Diverging to Low NOx

Background

Burner aerodynamics are essential to design and operation. Aerodynamics are established by throat velocity, airflow distribution, integrated and local swirl, recirculation parameters, and the quarl shape and size. While a lot of attention is given to the fuel side components such as gas nozzles and injectors, air flow accounts for roughly 95% of the mass flow through the burner and thus has a massive impact on performance. Over the years, various refractory throat designs have been implemented, but for Low-NOx burners, a diverging refractory throat provides the optimal aerodynamic conditions.

Analysis

In this case study, the diverging throat burner is compared to a converging throat burner with both Ansys Fluent CFD modeling and field results. The converging throat burner has fixed, high-spin vanes and no swirler/stabilizer (see drawings below). These design parameters combined to produce ultra-high spin to stabilize and shape the flame. The diverging throat burner is an axial flow burner with bluff body stabilization. These aerodynamic parameters define the size and intensity of the internal recirculation zone, also known as the IRZ. The IRZ is 3-dimensional zone of recirculating gases caused by a localized static depression at the burner outlet. This static depression causes hot gas to recirculate back into the primary combustion zone and mix with the incoming un-burnt fuel. The IRZ is responsible for flame stability, mixing, and proper primary zone combustion.

The CFD model showed that the converging throat overspun the air/fuel mixture, created a centrifuge effect, and caused the flame to strongly impact the side walls of the refractory chamber (see Figure 2). The CFD model of a diverging throat, bluff body stabilized STEP Variswirl burner showed that improved aerodynamics helped to better shape the flame and reduce impingement on the side walls (see Figure 2).

Conclusion

The aerodynamics of the diverging throat burner are optimal for Low-NOx performance. The IRZ creates a stable core flame and allows for the balance of the fuel to stage down the furnace, reducing NOx emissions. In the field, we have observed converging throat burners causing massive refractory damage, unstable combustion, and high NOx emissions. With minor fuel side changes and modifying air side aerodynamics to a diverging throat, these problems have been completely eliminated in multiple cases.

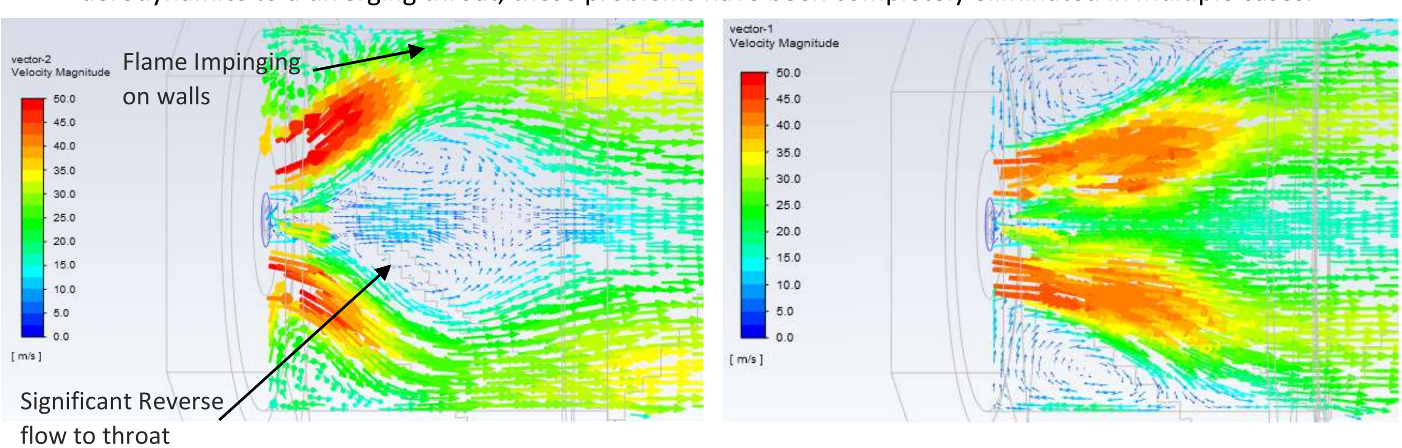

Figure 2: CFD Model Results, Velocity Profile Converging Throat (left), Diverging Throat (right)

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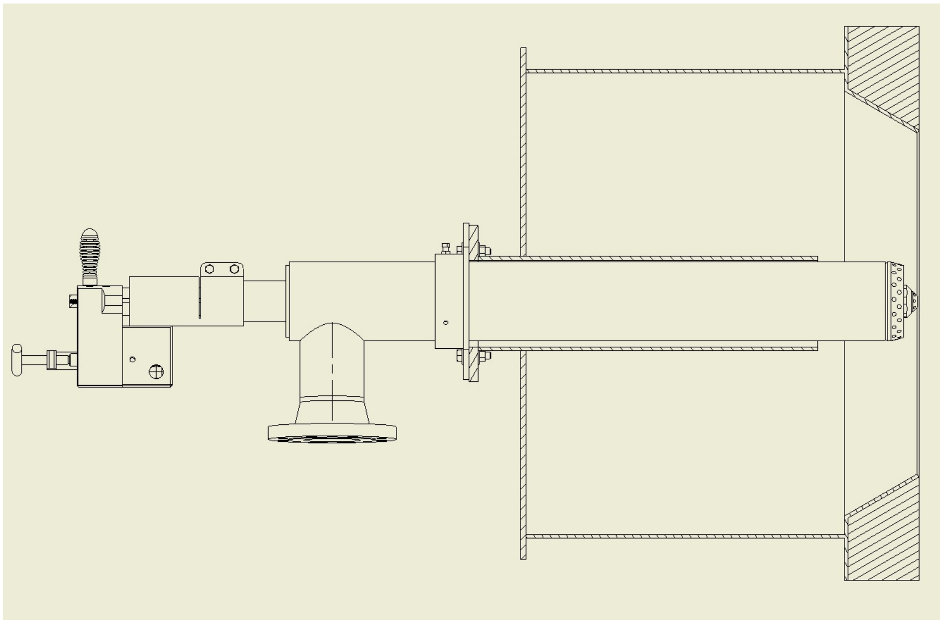
Before



After