Deflagration to Detonation Transitions: Predicting DDTs in hydrocarbon explosions

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ABSTRACT

Large quantities of hydrocarbons are being produced, manufactured, transported and stored, which can significantly increase the size and potential consequences of flammable vapor clouds in the event of release due to accidental loss of containment. One of the more devastating events upon ignition of large vapor clouds is if the flame transitions from a deflagration to a detonation in a region of considerable confinement or high object density. Deflagration to detonation transitions, otherwise known as DDTs, can possibly lead to explosion consequences orders of magnitude higher than their deflagration counterparts due to the severe overpressure associated with detonations, and more importantly, due to the potential contribution of the energy associated with flammable cloud outside of the congested and confined regions. In addition, recent explosion investigations have concluded that DDTs did indeed occur during the event and further enforce the need to identify under what circumstances DDTs can occur in petrochemical and process facilities.

This paper discusses our campaign to expand CFD predictions to include the prediction of deflagration to detonation transitions for various fuels including hydrogen, ethylene, propane and natural gas. The work includes validation against experiments conducted in a variety of configurations including: (1) closed pipes with obstacles; (2) other congested lab-scale geometries; (3) medium to large-scale 3-D obstacle configurations; and (4) large-scale geometries where DDT occurred upon flame propagation from confined to more open configurations. The CFD model has been extended to identify whether DDT is likely in a given scenario and indicate the regions where it might occur. The likelihood of DDT has been expressed in terms of spatial pressure gradients across the flame front. This parameter is able to visualize when the flame front captures the pressure front, which is one of the main mechanisms that may initiate a DDT. Reasonable agreement was obtained with experimental observations in terms of explosion pressures, transition times, and flame speeds. The DDT model is currently being extended to include a criterion for estimating the likelihood of DDT by comparison of the geometric dimensions with the detonation cell size of the fuel-air mixture. Application of this model to some recent explosion incidents will be discussed in the Part 2 as well as our ongoing testing campaign to investigate transitions at very large scales (2,500-5,000 m\textsuperscript{3}).