SCALING CRITERIA FOR INTERNAL GAS EXPLOSIONS IN CONNECTED VESSELS

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Accidental internal explosions of gaseous fuel–air mixtures occur in enclosures of complex geometry with obstructions, doorways, etc. The development of explosion is affected by the enclosure scale and a number of other factors and conditions which are not fully identified so far. This is the reason that large-scale internal explosions cannot be reliably simulated using laboratory-scale models. Purely geometrical scaling of a large-scale enclosure with internal obstructions does not allow one to reproduce gas explosion dynamics in laboratory conditions. The aim of this study is to determine theoretical scaling criteria for internal gas explosions in an enclosure partitioned by the orifice plate into two connected Volumes 1 and 2. The statement of the problem implied ignition and combustion of a homogeneous fuel–air mixture in Volume 1 with the outflow of the fresh mixture and combustion products through the orifice to Volume 2 and possible volumetric explosion followed by flame propagation in Volume 2. The problem was solved with due regard for heat loss to the enclosure walls by conductivity and radiation. Based on the analysis of the dimensionless governing equations for partitioned cylindrical enclosures, the following set of scaling criteria was derived: V_1/V_2 = idem; S/F = idem and U/a = idem, where V_1 and V_2 are the corresponding volumes, S is the cylinder cross section area, F is the orifice cross-section area, U is the mean burning velocity in Volume 1, and a is the sound velocity in the fuel–air mixture at initial conditions. The criterion U/a = idem is known to fail for enclosures of different geometrical scales due to various mechanisms and interactions inherent in flame acceleration. To hold this criterion, special means leading to purposeful increase in U in the laboratory-scale enclosures have to be applied. To verify this implication, multidimensional numerical simulations of internal gas explosions in geometrically similar partitioned enclosures were performed using Reynolds Averaged Navier–Stokes equations coupled with the k-epsilon turbulence model and a statistical model of turbulent combustion involving a detailed mechanism of methane oxidation. In order to hold the criterion U/a = idem in the small-scale enclosure (1:10 scale), the mean burning velocity was increased to the value inherent in the large-scale simulations either artificially or by increasing the initial turbulence intensity. As a result, the predicted explosion dynamics appeared to be identical in the enclosures of different geometrical scales both qualitatively and quantitatively, i.e. substantiated the scaling criteria derived. This work was supported by the International Science and Technology Center project #2740.