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Large Eddy Simulation and experimental study on vented gasoline-air mixture explosions in a semi-confined obstructed pipe

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Highlights

- 1. LES and experimental studies were conducted to investigate vented gasoline-air mixture explosions in an obstructed pipe.
- 2. Interaction between flame propagation and obstacles was investigated by LES study.
- 3. Mechanism of overpressure dynamics was assumed to be associated with the mass flow rate and flame surface area.
- 4. Effects of initial gasoline vapor concentrations and obstacle number on gasoline-air mixture explosions were investigated.

Abstract: In this work, LES simulation coupled with a TFC sub-grid combustion model has been performed in a semi-confined pipe (L/D=10, V=10L) in the presence of four hollow-square obstacles (BR=49.8%) with circular hollow cross-section, in order to study the premixed gasoline-air mixture explosions. The comparisons between simulated results and experimental results have been conducted. It was found that the simulated results were in good agreement with experimental data in terms of flame structures, flame locations and overpressure time histories. Moreover, the interaction between flame propagation process and obstacles, overpressure dynamics were analyzed. In addition, the effects of initial gasoline vapor concentration (lean (ϕ=1.3%), stoichiometric (ϕ=1.7%) and rich (ϕ=2.1%)), and the number of obstacles (from 1 to 4) were also investigated by experiments. Some of the experimental results have been compared with the literature data. It is found that the explosion parameters of gasoline-air mixtures (e.g. the maximum overpressure peaks, average overpressure growth rates, etc.) are different from some other fuels such as hydrogen, methane and LPG, etc.

Keywords: Vented gasoline-air mixture explosions; Large Eddy Simulation; Obstacles

Nomenclature

A	model constant
BR	blockage rate
c	reaction progress variable
C_s	Smagorinsky constant
D_i	distance between two adjacent obstacles
$(dp/dt)_{ave}$	average overpressure growth rate
eq	chemical equilibrium
H(x)	Heaviside function
l_t	turbulence length scale
L_i	distance between the first obstacle and the ignition point
L/D	aspect ratio
N#	order of literatures
No.	number of obstacles
P_{max}	maximum overpressure peak
P_E	maximum overpressure peak of experimental results
P_L	maximum overpressure peak of LES results
S_c	reaction progress source term
$\tilde{S}_{ij}$	stain tensor rate
$S_{c_{eff}}$	effective Schmidt number
S_{fmax}	maximum flame speed
S_f	flame speed
t	time to reach the maximum overpressure peak
t_E	time to reach the maximum overpressure peak of experimental results
t_L	time to reach the maximum overpressure peak of LES results
u	unburnt reactant
u'	sub-grid velocity fluctuation
u	velocity