Towards Analytical Predictive Scenario of a Coalmine Burning Accident

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Among industries dealing with flammable gases and other combustible materials, historically, coalmining has ones of the highest fatality and injury rates. To reduce the risk of accidental explosions in coalmines, a fundamental physical understanding of the combustion processes in a premixed methane/air/coal-dust environment is critically needed. The present work is a step in this direction. Specifically, the key stages and characteristics of the premixed flame evolution in a typical mining passage, such as the flame propagation velocities, acceleration rates and run-up distances, are scrutinized by means of the analytical endeavors, with a particular focus on the dynamics of an expanding flame front and on flame acceleration due to a "finger"-like flame shape. First, an embryonic premixed flame, accidentally sparked at a point, expands globally-spherically, with subsequent self-acceleration due to the hydrodynamic (Darrieus-Landau; DL) combustion instability. Second, when a flame starts approaching a passage wall, a transition from a globally-spherical front to a finger-shaped one occurs, with an onset of another acceleration mechanism. As a result, the "expanding" and "finger" flame acceleration scenarios are combined into a unified analytical formulation. Starting with an incompressible approximation, we then incorporate the effect of compressibility into the analysis. The formulation also involves the dependences of the thermal-chemical flame parameters, such as the laminar flame speed, on the coal dust properties, such as the dust particles size and concentration.

Keywords: premixed flame acceleration; expanding flames; "finger" flames; dusty-gaseous combustion; gas compression; coalmine fire safety.