Front propagation in the interaction of gases to model a fuel tank inerting process with a nonlinear parabolic operator

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Abstract

Purpose – The objective of this study is to model the propagating front in the interaction of gases in an aircraft fuel tank. To this end, we introduce a nonlinear parabolic operator, for which solutions are shown to be regular.

Design/methodology/approach – The authors provide an analytical expression for the propagating front, that shifts any combination of oxygen and nitrogen, in the tank airspace, into a safe condition to avoid potential explosions. The analytical exercise is validated with a real flight.

Findings – According to the flight test data, the safe condition, of maximum 7% of oxygen, is given for a time $t = 45.2$ min since the beginning of the flight, while according to our analysis, such a safe level is obtained for $t = 41.42$ min. For other safe levels of oxygen, the error between the analytical assessment and the flight data was observed to be below 10%.

Originality/value – The interaction of gases in a fuel tank has been little explored in the literature. Our value consists of introducing a set of nonlinear partial differential equations to increase the accuracy in modeling the interaction of gasses, which has been typically done via algebraic equations.

Keywords Nonlinear parabolic equations, Regularity, Inerting, Finite speed

Paper type Research paper

1. Introduction

On July 1996, a Boeing 747–131 operated by the aeronautical transport company Trans World Airlines (TWA) caught into a fire when flying over the Atlantic Ocean (refer to (Aircraft Accident Report, n.d) for a complete description). After having carried out a costly investigation, the most probable root cause was identified as a spark occurred in an empty fuel tank with plenty of fuel vapors. This fact may be additionally aggravated by the action of the air conditioning machines located beneath the affected tank.

As a postulated solution to avoid similar unsafe occurrences, the aviation authorities proposed the need for producing a inert fuel tank airspace (refer to (FAA. Advisory Circular Ref. 25.981-1C, n.d) for further details). The inspiring idea consisted of removing the oxygen and replaces it by an inert gas. Simply and costless, the oxygen is replaced by the own nitrogen presented in the air. Further test campaigns, together with analysis about flammability of fuel tanks, were conducted to determine a safe and conservative maximum level of oxygen concentration to minimize the risk of explosion and hazards. Such a level was fixed at a maximum of 7% for civil aircrafts (hence > 93% of nitrogen presented in the tank airspace) in accordance with the guidelines from the aircraft certification authorities (see (Fuel tank flammability reduction, 2008) for additional insights about this requirement along with acceptable means of compliance).

AMS Subject Classification — 35K55, 35K57, 35K59, 35K65

Conflicts of interest: The corresponding author confirms that there are not any conflicts of interest to declare.

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