Reconstruction of the Fatal 1985 Manchester B737 Fire using Fire and Evacuation Simulation

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On the 22nd of August 1985, a B737-236 suffered an uncontained engine failure and fire during its take-off roll at Manchester Airport, England, resulting in 55 fatalities among the 131 passengers and 6 crew on board. During the accident, the external fuel fire accessed the cabin after the burn-through of the fuselage. In this paper, this accident is numerically investigated using the coupled fire and evacuation simulation tools, SMARTFIRE and airEXODUS. The aim of this work is to investigate the impact of door opening times on the evacuation and survivability during this fire evacuation. The work is in two parts: (1) attempting to reconstruct the actual fire incident and resulting evacuation using the known facts derived from the official investigation and (2) investigating the impact of door opening times on the aircraft fire development and subsequent evacuation and survivability.

1. Reconstruction of the fire development and evacuation processes

As many of the key details concerning the fire development required for a detailed fire simulation are uncertain a sensitivity study on the key variables required for the fire simulation is undertaken. The key parameters that are studied in this analysis are:

- The Heat Release Rate (HRR) of the external fire;
- The start time of the cabin burn-through and the time required for cabin burn-through;
- The burn-through time for the cabin ceiling;

The results of these fire simulations are then coupled to an evacuation simulation to predict the impact of the fire on the evacuating passengers. The passengers are exposed to the fire hazards determined from the fire simulations which include; temperature, radiative flux, concentrations of toxic gases, low oxygen and smoke obscuration (via light extinction coefficient). In these simulations, the following parameters are taken from the accident report and used as input parameters:

- An external wind of 7 kts;
- The size and location of the cabin burn-through;
- Exit opening times for the R1 (70s), L1 (25s) and ROW (45s) exits;
- Seating location of the passengers;
- The exit used by each survivor;

The material properties of the cabin interior materials are taken from various publications and are used as inputs for the combustion model, flame spread model and toxicity model in the fire simulations. The external fire is simplified as a volumetric source of 3 m long, 1 m wide and 0.5 m high. Its size is sufficient for the flame to cover the observed burn-through of the fuselage.

The most appropriate values for the unknown parameters are derived from these sensitivity simulations. This is achieved by modifying these parameters and comparing the outcome of the fire and evacuation analysis with the key known outcomes. The values of the unknown parameters which result in the closest match to the known outcomes are considered to be plausible approximations to these unknown parameters. The key reported outcomes that are used in this evaluation are:

- The seats on the right side of cabin are more severely damaged than those on the left side of the cabin;
- The location of the damaged seats;
- 55 fatalities (passengers and crew) resulting from the fire and the seat locations of the fatalities;
- 23 of the 51 survivors who exited via exits R1 and L1 avoided being immersed in thick smoke

The parameter set which produces the closest agreement with the known outcomes has a burn-through time of 80 seconds after the aircraft stopped and it takes 50 seconds for the size of the burn-through area to reach the reported burn-through area. The burn-through time for the ceiling is approximately 130 seconds. This scenario results in 52 fatalities. The scenario with these parameters is called Base Scenario hereinafter and used in the investigation of the impact of the exit opening times on the resulting evacuation.

2. Impact of exit opening times on the evacuation and survivability

Using the Base Scenario, several key factors that were highlighted in the official investigation as being influential to the fire development and survivability are investigated. In particular we consider the exit opening times, that of the rear R2 exit and the forward R1 exit. Both exits were the subject of controversy, the R2 exit because it was opened (but not used by passengers) thereby allegedly allowing smoke and heat to enter the cabin making the situation worse and the R1 exit, because it was opened late delaying the evacuation.

To investigate the effects of the opening of the R2 exit on the fire progress and resulting evacuation, a scenario with Exit R2 closed throughout the scenario is simulated. When exit R2 is closed throughout the fire, the fire spreads more rapidly inside the cabin than in the Base Scenario, resulting in 65 fatalities, an increase of 25%. Exit R1 was opened 70 seconds after the aircraft completely stopped due to an exit malfunction. A scenario in which with Exit R1 was opened after 10 seconds resulted in 40 fatalities, a decrease of 23% compared with Base Scenario. These results support the view that opening the rear exit was not a mistake and did not contribute to the high loss of life, while the malfunction of the forward exit did contribute to the significant loss of life in this accident. This work also highlights the great importance of the prompt opening of viable exits in aircraft emergencies involving fire.