Post-Crash Cabin Fire and Evacuation as a Function of Cabin Ventilation: A Numerical Study using Fire and Evacuation Simulation

Z. Wang, F. Jia, M. Togher, E.R. Galea and P.Lawrence
Fire Safety Engineering Group
University of Greenwich, London SE10 9LS UK
http://fseg.gre.ac.uk

In this paper we examine the impact different exit openings have on post-crash fire development and evacuation for aircraft cabin geometries similar to a B737 or A320. It is well known that all commercial passenger aircraft must satisfy the so called "90 seconds certification requirement" (see FAR 25.803 [1]). This involves the assumption that 50% of the exits, usually on one side of the aircraft are open and available for evacuation. The impact of having different combinations of exits available on the egress time was discussed in an earlier paper presented at the last conference [2]. Also at that conference, the impact of cabin ventilation on post-crash cabin fires was investigated numerically using the C133 aircraft geometry [3] and the impact this may have on evacuation from the C133 geometry was also examined [4]. While this work is of interest, it does not represent an actual commercial aircraft geometry. In this paper we continue the study by considering the impact of fire and evacuation within an aircraft geometry which is similar to that of common narrow body commercial aircraft such as the B737 or A320. It should be noted that in the earlier study, the airEXODUS evacuation simulation software predicted that under strict evacuation certification conditions, the B737 configuration (149 passengers and 3 cabin crew) is likely to produce on-ground evacuation times of between 67.0 s and 76.8 s with a mean of 71.2 s and a 95$^{th}$ percentile time of 73.8 s [2]. The time achieved by this aircraft in the actual FAR 25.803 certification trial falls on the predicted evacuation time curve and is between the minimum and mean predicted times.

In this study we address the following questions:

Given, an aircraft configuration that has satisfied the FAR 25.803 requirements, a post-crash fire of given size and a cabin rupture of given size opposite the external fire:

- How does cabin ventilation produced by various cabin openings affect the time to flashover?
- For an exit combination similar to that required by the standard FAR 25.803 certification trial, can the passengers and crew be safely evacuated and how long will be required?
- For other exit combinations, can the passengers and crew be safely evacuated and how long will be required?

As in the earlier studies [2,3,4] the SMARTFIRE CFD fire simulation tool and the airEXODUS aircraft evacuation simulation tools are used. The aircraft geometry, as it appears within the fire simulation tool SMARTFIRE is depicted in Figure 1. In this study six exit combinations are examined, including the normal certification exit configuration, two other exit configurations commonly found in real accident situations and three exit configurations which may result from this particular fire scenario (see Table 1).

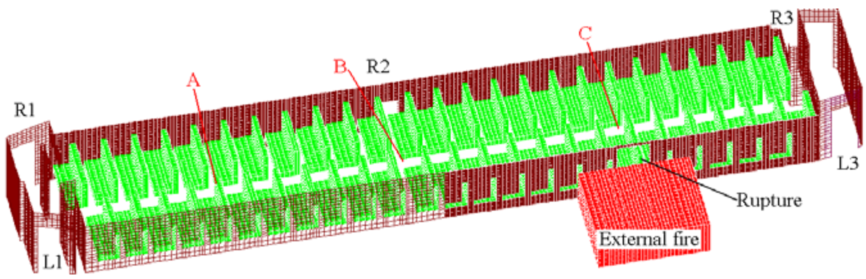


Figure 1: Aircraft geometry generated using SMARTFIRE

The fire model and material properties of interior panels used here is the same as that used in the earlier simulation of the C133 fire test [3] however, the flame spread model has been further refined. In the earlier C133 study, the dimensions of the cabin rupture was equivalent to that of a Type A exit (1.06 m$\times$1.93 m), in the current study, the rupture is smaller with dimensions of 0.89 m $\times$ 1.65 m and is located between the L2 and L3 exits as shown in Figure 1. The heat release rate for the external kerosene fire used in these simulations is 7.7 MW. The predicted fire hazards considered in this analysis include: temperature, heat fluxes, concentrations of carbon monoxide, carbon dioxide and oxygen, and smoke optical density. These hazards are used by the Fractional Effective Dose toxicity model and human behaviour model within airEXODUS to determine their effect on the passenger population. Each evacuation scenario with coupled fire was run 100 times using the same population. The evacuation times quoted in Table 1 represent the on-ground times.

Table 1: Results from fire and evacuation simulations

| Scenario | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Openings | R1 | R1, R2, L1 | R1, R3 | R1, R2, R3 | R1, R3, L1 | R1, R2, R3, L1 |
| Time to flashover (s) | 225 | 275 | 285 | 325 | 340 | 355 |
| Average Total Evacuation Time without fire (s) | -- | 98.1 | -- | 71.2 | 77.7 | -- |
| Average Total Evacuation Time with fire (s) | 236.2 | 259.9 | 296.7 | 151.3 | 270.8 | 142.2 |
| Average Crawling Time (s) | 83.8 | 86.3 | 80.6 | 32.3 | 81.5 | 46.8 |
| Average number of Fatalities | 61.5 | 13.4 | 3.0 | 2.0 | 1.7 | 1.9 |
| 1>FIH>0.5 | 10 | 24 | 7 | 2 | 3 | 2 |

Significant findings from this analysis include:

- Flashover occurs between 225 and 355 seconds for the six scenarios. In the earlier C133 fire analysis there were some exit configurations (in which the cabin rupture was opposite an open exit) where flashover was not observed within the first 480 seconds [3]. Differences in time to flashover between the earlier C133 study [3] and the current study are due to differences in the location of the rupture and size of the exits used in the current study.
- Time to flashover is strongly dependent on the number and location of the cabin openings relative to the cabin rupture. Time to flashover can be extended by as much as 60% depending on the cabin ventilation conditions.
- For the certification exit configuration scenario, flashover occurs after 325 seconds.
- In the certification exit configuration scenario (scenario 4), the evacuation time increases from an average of 71.2 seconds without fire to 151.3 seconds in the fire scenario an increase of approximately 113%. The increase in egress time is primarily due to the decease in walking speed due to the presence of smoke and the relatively long average crawl time (32.3 seconds) experienced in this scenario. The certification exit configuration scenario results in an average of 2 fatalities and 2 passengers suffering from severe burn injuries.
- The exit scenario which is similar to the 1985 Manchester fire incident (Scenario 2) results in an egress time some 164% longer than the equivalent non-fire case and results in an average of 13.4 fatalities and 24 severely injured passengers.
- The worst case, Scenario 1 with only a single exit open (R1), results in an evacuation time of 236.2 seconds and an average of 61.5 fatalities and 10 severely injured passengers.
- Scenarios in which exits at both ends of the cabin are open and used by passengers result in the smallest number of fatalities. In these cases (Scenarios 3-6), the number of fatalities is reduced to a maximum of 3 from between 13 to 62 for scenarios 1 and 2.

The findings of this analysis will be discussed in detail and the limitations of the study will be highlighted.

## References


1. FAR Part 25.807 Airworthiness Standards. Transport Category Airplanes. Including amendment 25-67 as published in the Federal Register on June 16th, 1989, Washington DC, USA, 1989.
2. Galea, E.R., Togher, M., Lawrence, P., “Investigating the Impact of Exit Availability on Egress Time using Computer based evacuation simulation.” Proceedings of the International Aircraft Fire & Cabin Safety Conf, Oct 29 – Nov 1, 2007, Atlantic City USA.
3. Wang Z., Galea E.R., Jia F., A computational study of the characteristics of aircraft post-crash fires. Proceedings of the International Aircraft Fire & Cabin Safety Conf, Oct 29 – Nov 1, 2007, Atlantic City USA.
4. Galea, E.R., Wang, Z., Togher, M., Jia, F., and Lawrence, P., “Predicting the likely impact of aircraft post-crach fire on aircraft evacuation using fire and evacuation simulation”, Proceedings of the International Aircraft Fire & Cabin Safety Conf, Oct 29 – Nov 1, 2007, Atlantic City USA.