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Modeling and assessment of civil aircraft evacuation based on finer-grid

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HIGHLIGHTS

- The internal structure of aircraft can be well reproduced for the finer-grid.
- The effect of seat area and others on escape process is considered.
- The model takes into account pedestrian's hesitation before leaving exits.
- An optimized rule of exit choice is defined.
- An assessment procedure of aircraft evacuation safety is presented.

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ABSTRACT

Studying civil aircraft emergency evacuation process by using computer model is an effective way. In this study, the evacuation of Airbus A380 is simulated using a Finer-Grid Civil Aircraft Evacuation (FGCAE) model. In this model, the effect of seat area and others on escape process and pedestrian's "hesitation" before leaving exits are considered, and an optimized rule of exit choice is defined. Simulations reproduce typical characteristics of aircraft evacuation, such as the movement synchronization between adjacent pedestrians, route choice and so on, and indicate that evacuation efficiency will be determined by pedestrian's "preference" and "hesitation". Based on the model, an assessment procedure of aircraft evacuation safety is presented. The assessment and comparison with the actual evacuation test demonstrate that the available exit setting of "one exit from each exit pair" used by practical demonstration test is not the worst scenario. The half exits of one end of the cabin are all unavailable is the worst one, that should be paid more attention to, and even be adopted in the certification test. The model and method presented in this study could be useful for assessing, validating and improving the evacuation performance of aircraft.

1. Introduction

According to the Federal Aviation Regulations (FAR) [1], "for airplane having a seating capacity of more than 44 passengers, it must be shown that the maximum seating capacity can be evacuated from the airplane to the ground under

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simulated emergency conditions within 90 s''. Furthermore, an actual demonstration using the test criteria, i.e. ''90 s certification test'', is needed generally in the airworthiness certification. For instance, Airbus undertook a full-scale evacuation test for the A380 in March 2006. In this test, 853 passengers, 18 cabin crew, and two pilots were evacuated in 78 s [2].

However, there are several difficulties with the ''90 s certification test'' [3]. First, there is considerable threat of injury to test participants. Published statistics for the periods 1972 and 1991 reveal that 378 volunteers (or 6% of participants) sustained injuries ranging from cuts and bruises to broken bones [4]. And especially 33 people were injured, including one whose leg was broken, in the evacuation test of A380 [5]. Second, a real emergency scenario is so difficult to reach that there may be a discrepancy between test and actual evacuation. For example, in the Manchester disaster of 1985, the last passenger escaping from the burning B737 aircraft costs 5.5 min, but in a certification test 15 years earlier, the entire load of passengers and crew finished evacuation in 75 s [6]. Third, each full-scale evacuation demonstration test will be extremely expensive and time-consuming.

Consequently, along with the development of computer simulation technology, researchers began to simulate the evacuation process of civil aircraft under emergency. On the one hand, the simulation would be a useful supplement for actual demonstration test [3], on the other hand, simulated results can be used to assist the aircraft safety evacuation design and as a basis for optimization of aircrew emergency disposal procedures [7].

Evacuation simulation technology is widely used in the field of construction. Many kinds of evacuation models were built, including social force model [8], lattice gas model [9–11], cellular automata model [12], multi-grid model [13] and agent-based model [14]. Most of the existing evacuation models have been used for building design and certification [15–17].

Nevertheless, because of the particularity of the space, structure and facilities, the emergency evacuation process in aircraft is obviously different from building. Therefore, the evacuation model for building cannot be directly applied to the evacuation simulation of civil aircraft. Recently, researchers had built several special evacuation models for aircraft, such as STRATVAC [18], airEXODUS [19], VacateAir [20], and Ped-Air [21]. Using these models, the effect of environmental condition (such as exit setting [22] and crew' guidance [21,23]), passengers' physiological characteristics [24,25] (such as gender, age and size) and psychological characteristics (such as panic [26] and hesitation [27]) on the evacuation process of aircraft was studied.

In most of the existing aircraft evacuation models, the size of the grid is matched with the pedestrian size. As a result, the pedestrians queue in order and the size of exits, obstacles and aisle has to equal to the integral multiples of the pedestrian size. However, in reality pedestrians move in dislocation, and the size of exits, obstacles and aisle are irregular and not integral multiples of pedestrian size. For these reasons, we have built a Finer-Grid Civil Aircraft Evacuation (FGCAE) model [28], in which the space is discretized into small grids with the size of 0.1 m × 0.1 m. In this study, it is aimed to simulate and assess the evacuation of A380 based on an improved FGCAE model. The rest of this paper is organized as follows. In Section 2, the FGCAE model with some specific rules for A380 is introduced. The effect of update procedure, seat, hesitation, and set of available exits on the simulation results are discussed in Section 3. In Section 4, we present an assessment procedure of aircraft evacuation safety. Finally, in Section 5, we close the paper by summarizing our findings and suggestions.

2. Modeling

The double-deck A380 is the world's largest commercial aircraft flying today, with capacity to carry 525 passengers in a comfortable three-class configuration, and up to 853 in a single-class configuration. In this study, to compare with the actual test, the capacity of 853, i.e. the single-class configuration is considered. Moreover, since that both decks are fully self-supporting and can be treated as separate cabins [29], only the main deck is modeled here for simplicity.

2.1. Space meshing

Fig. 1(a) shows a normal configuration of the main deck of A380, and there are totally 400 seats. However, during the evacuation test, to represent a 100%-load factor, 538 ''passengers'' were seated on the main deck, as well as 11 cabin crewmembers and two pilots in the cockpit [30]. Therefore, in the model, a configuration of 538 seats is used, as shown in Fig. 1(b). The cabin is first discretized into grids with the size of 0.1 m × 0.1 m, which are divided into four categories: normal passable grids, seat grids, obstacle grids and exit grids, correspond to what they represent. The normal passable grids represent area that passengers can easily pass through, such as aisle between columns of seats and open ground in front of exits. The obstacle grids include normal obstacles and seat back, and each seat back occupies 1 grid site in thickness. The seat grids indicate the personal space passengers have when sitting, which are also passable for passengers but by sideways. There are five pairs (10) of oversized Type A [1] emergency exits on the main deck and each exit is about 1.07 m wide [29]. In the model, the exits are symbolized by $E_n (n = 1, 2, \ldots 10)$, and each exit occupies 11 grids sites in width to match the actual size.

2.2. Drift direction determining

In this study, the drift direction denotes the direction that pedestrians prefer to move with a higher probability. It is recognized that in evacuation process pedestrians prefer to select the nearest exit and then move in the direction leading