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論文

A Study of SHEL Model Application to Passenger Brace Position Information of Korean Air Carriers

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우리나라 항공사의 승객 충격방지 자세 정보에 대한 SHEL모델 적용 연구

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초 록

항공기 추락 시 충돌충격단계에서 사상자가 가장 많이 발생하는 것으로 나타나고 있다. 대부분의 경우, 승객들은 두부손상으로 의식을 잃게 되어 비상탈출에 실패하여 사망에 이르게 된다. 이에 대한 대응책으로 항공기 제작사들은 내구성이 강화된 항공기 좌석을 설계 및 제작하여 설치하고 있다. 객실에서는 승객들이 충격방지자세를 취함으로써 부상을 최소화할 수 있다. 승객들에 대한 충격방지자세 안내는 모든 항공사가 시간적 여유가 있는 비상상황에서만 객실승무원이 안내방송과 함께 시범을 보이도록 절차가 수립되어 있다. 그러나 갑작스런 사고의 경우 승객들은 충격방지자세에 대한 정보를 전달받지 못한 상태에서 사상의 위험에 직면하게 된다. 본 논문은 SHEL 모델을 적용하여 승객과 사상자발생 환경, 승객과 충격방지를 위한 안전절차, 승객과 승객안전정보 전달매체, 승객과 객실승무원등의 상호작용에 내재된 위해요소를 체계적으로 규명하고 객실안전에 대한 법규 및 절차 등의 개정을 제시함으로써, 항공기사고로 인한 사상자 발생에 대한 근본적인 대안을 제시하여 항공안전 증진에 기여하고자 한다.

Key Words : Aircraft accident(항공기사고), Fatalities(사망자), Survivability(생존성), Aircraft crash impact(항공기추락충격), Brace position(충격방지자세), Passengers(승객), Cabin crew members(객실승무원)

1. Introduction

When an aircraft crashes, multiple and sequential impacts take place, which result in serious and fatal injuries. Adoption of the protective brace position minimizes the physical effects on human bodies, thus helps to maximize the probability that individuals will still be mobile enough to undertake emergency evacuation from the aircraft on their own, that is directly linked with survivability. Having realized the importance of the brace position, some foreign air carriers have initiated to include the brace position in their pre-takeoff passenger briefing while Korean air carriers have the brace position depicted as pictograms/pictorials on the passenger safety briefing card. Nonetheless most passengers seldom read the briefing card, even read, the instructions cannot be comprehended, for which there are no

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regulations as to content or format. As a result, the passengers on Korea registered air carriers hardly have access to information about the brace position, which is critical for their potential survivability in an aircraft accident.

By means of application of SHEL model, this paper intends to identify the hazards in cabin safety information on the brace position, and suggests the necessity to establish the corresponding national legal provisions.

2. Literature Review and Methods

2.1 Theoretical background

2.1.1 Aircraft accident fatalities

Type of Operation	All Accidents		Fatal Accident		Onboard Fatalities (External Fatalities)*		Hull Loss Accident	
	1959 -2014	2005 -2014	1959 -2014	2005 -2014	1959 -2014	2005 -2014	1959 -2014	2005 -2014
Passenger	1,501	327	493	56	29,165 (792)	3,888 (124)	704	118
• Scheduled	1,380	302	447	53	25,039	3,872	634	111
• Charter	121	25	46	3	4,126	16	70	7
Cargo	265	65	79	13	273 (342)	41 (15)	178	39
Maintenance test, ferry, positioning, training, and demonstration	124	12	44	3	208 (66)	17 (0)	76	8
Totals	1,890	404	616	72	29,646 (1,200)	3,946 (139)	958	165
U.S and Canadian Operators	564	75	182	12	6,202 (381)	26 (7)	227	25
Rest of the World	1,326	329	434	60	23,444 (819)	3,920 (132)	731	140
Totals	1,890	404	616	72	29,646 (1,200)	3,946 (139)	958	165
*External fatalities include on-ground fatalities as well as fatalities on the other aircraft involved.								

Fig. 1 Statistical Summary of Commercial Jet Airplane Accidents [1]

Although air travel is now safer than ever before, during the 55 year period from 1959 to 2014 there were 1,501 accidents involving passenger carrying commercial jet aircraft in which 29,165 people were killed(Fig. 1). Despite that a large number of fatalities have been recorded in aircraft accidents, the U.S. National Transportation Safety Board(NTSB) states from a result of investigations for all the accidents involving U.S. air carrier flights operating under Title 14 Code of Federal Regulations Part 121, 1983 through 2000 that the survivability in commercial aircraft accidents is 95.7% [2].

Many people appear to believe that if the aircraft crashes, death is inevitable but all in all over 70% of airline accidents are survivable. 71% of the people who die in survivable crashes do so, in many cases, it's because they are unprepared for the aircraft crash [3].

2.1.2 Aircraft emergency landing types

Following the aircraft accident, there are basically two types of aircraft emergency landing/ditching: 'unanticipated/unplanned' or 'anticipated/planned'. Aircraft accidents are caused by various factors such as flight crew members, aircraft technical malfunction, adverse meteorological conditions, air traffic control associated factors, maintenance deficiencies. Still the most common cause is known to be the flight crew member related human factors that leads to 'unanticipated/unplanned emergency evacuation [4]. Because this type of accident occurs inadvertently and often catastrophically, leaving no time for the crew members or passengers to take any preparatory safety measures in the cabin. An example of this type of accident is that of Controlled Flight Into or Toward Terrain (CFIT). Since the CFIT accident occurs while the flight crew member do not recognize an impending danger, the aircraft is usually totally destroyed, with minimal or no survival of passengers and crew members [5].

1) Case of an anticipated emergency landing

"On January 10, 2010, United Airlines flight UA634 departed Chicago-O'Hare International Airport, IL (ORD) left the gate at 05:51 on a domestic passenger flight to Newark-Liberty International Airport, NJ (EWR). The flight was expected to land at Newark about 09:00 local time. While on finals, about 08:54 the crew apparently experienced problems getting the undercarriage down and locked. The crew carried out a missed approach and climbed to an altitude of 2000 feet. The flight circled the area west of the airport before a new approach was carried out to runway 04L. The

airplane landed with the right main gear retracted and came to rest on the runway with the no.2 engine touching the runway surface. An Airbus A319-131, registered N816UA, was damaged when it landed at Newark-Liberty International Airport, NJ (EWR) with its right hand main landing gear retracted. All the occupants were evacuated using the emergency slides" [6].

2) Case of an unanticipated emergency landing

"On April 15, 2002, at about 11:21, a Boeing 767-200ER (CCA 129), en route from Beijing, China to Busan, Korea, crashed during a circling approach to the runway. The wreckage was found on Mt. Dotdae at an elevation of about 200 meters and about 5 km north of the runway threshold. One captain, one first officer and one second officer, eight cabin crew members, and 155 passengers were on board at the time of the accident. Of the 166 persons on board, 37 (including the captain and two cabin crew members) survived, while the remaining 129 occupants (including the two copilots) were killed. Surviving occupants could not use the emergency slides and evacuated through holes and gaps in the aircraft wreckage" [7].

2.1.3 Factors minimizing fatalities & injuries

A number of different factors have been developed and implemented to increase the overall safety of air travel, specifically to improve survivability of the aircraft accident. At the intra-accident stage, improvements to the design of aircraft, including cabin fittings such as 16g seats, have further contributed to reducing the death and injury rate [8].

However, among this kind of cabin safety improvements, the passenger is treated as an essentially inert object and none represent comprehensive and specific measures during the accident when passengers can take spontaneous and appropriate actions to protect themselves from serious or fatal injury. Passengers obviously need to have knowledge about what these actions are and how to undertake them. In all aircraft crashes, passenger safety relies on three main and consecutive and linked steps: crash protection, rapid evacuation and post-evacuation survival. Thus, to achieve the final step, passengers must achieve crash protection by adopting the protective brace position to minimize the physical effect from the multiple impacts that the aircraft undergoes in a crash. Passengers then need to become mobile to be able to undertake an emergency evacuation from the aircraft. If they are unable to do so, then the probability of their leaving the aircraft decreases, thus decreasing survivability.

2.2 Application of SHEL model

SHEL model represents software, hardware, environment and liveware. As for this study, all the SHEL model components are in association with the brace position: Software means the corresponding legislation that is Flight Safety Regulations. Hardware means the pre-takeoff passenger briefing and the briefing card, the environment means the aircraft crash impact stage, liveware means passengers and cabin crew members (Fig. 2).

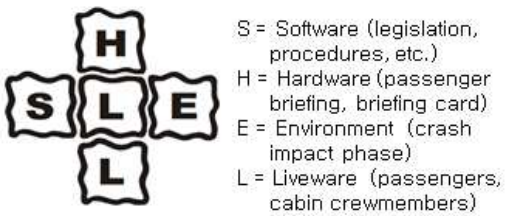

Fig. 2 SHEL model [9]

2.2.1 Hazard identification

1) Liveware-Environment

Fatal injury occurrence of impact phase: Whether anticipated or not, most emergency landings are linked with very large forces of impact, starting with the initial contact with the terrain, and then progressing through the subsequent and varying destruction of the aircraft itself. The impact forces usually result

in fatal/serious injuries, and the commonest cause of injuries is the sudden deceleration from an aircraft hitting the ground or water [10]. Head injury is very common in aircraft accidents that causes or contributes to the cause of the death [11]. Thus the first phase of fatal injury occurrence in the aircraft accident is that of the crash impact.

Using statistics from 17 accidents to transport category aircraft during the period from 1996 to 1993 where occupant fire injuries were sustained, and fire penetration of the passenger cabin occurred as a result of ground fires released a schematic showing a "survivability chain for an accident scenario" (Fig. 3). When an aircraft carrying 100 occupants crashes, 20 individuals would be killed by the impact, another 20 individuals seriously injured, and 60 injury-free survivors. Then in the second phase, of the 20 with serious impact-related injuries, 5 will die in the fire (and also from their injuries) while another 5 seriously injured will suffer burns but survive. Of the 60 who survived the impact without injury, 5 will succumb to the fire and 10 will suffer serious burns. Thus, 30 individuals will die, either on impact or in the subsequent fire; 25 individuals will suffer serious impact or fire-related injuries, and 45 individuals will survive uninjured. The message from this schematic is as to what the fundamental factors are that determine crash survivability, starting from the crash impact phase with most fatalities.

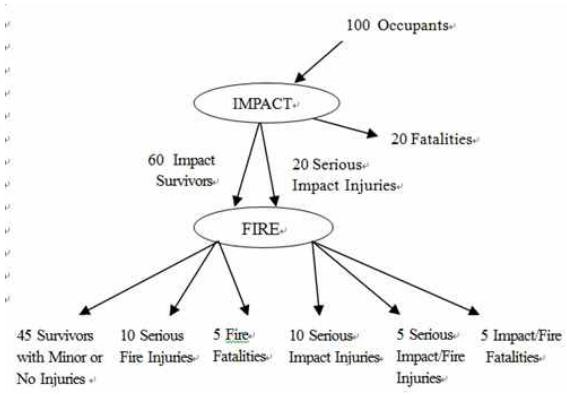

Fig. 3 Example of Survivability Chain for An Accident Scenario [12]

Importance of brace positions in the aircraft crash survivability: Although improvements in cabin seating and seat belt design have contributed to the reduction in casualties occurring in the impact phase, cabin crew members can further help passengers survive an aircraft accident with less serious injuries if they provide adequate briefing to passengers on the recommended brace position and also urge the passengers to use the positions during an emergency. A report from the NTSB identified several accidents in which passengers who were in a brace position sustained significantly less severe injuries than did other passengers. There were subsequent recommendations for air carrier-passenger briefings to include reference to the appropriate emergency brace positions [13]. For an example, a twin engined aircraft with 16 passengers onboard crashed during a landing approach. At the time of the accident, there was no warning of the imminent accident, and passengers were sleeping or reading. One passenger woke up, looked out the window and saw the aircraft was about to hit trees. He immediately lowered his head and braced his arms and knees against the seat back in front of him. He suffered a fractured leg and wrist and a scalp wound. He was the only survivor [14].

As revealed in the FAA's extensive research performed on brace-for-impact positions with the use of anthropomorphic dummies, evidence indicates that the brace position can make the difference between surviving or not surviving an aircraft crash [15]. The Protection & Survival Research Laboratory of Civil Aerospace Medical Institute (CAMI) conducted research and tests with respect to establishing 'brace for impact positions' for passengers and cabin crew members. In order to establish a best brace for impact position for each person, it would be necessary to know the size and physical limitations of the individual, the seating configuration, the type of emergency, and many other factors. There are two primary reasons for bracing for impact. One is to reduce flailing, having the occupant flex, bend,

or lean forward over their legs can reduce flailing. The other is to reduce secondary impact: repositioning of the body (particularly the head) against the surface can reduce secondary impact. Depending on the needs of air carriers' management strategies, an aircraft may have seating arrangements of very small seat pitches or a combination of small and large seat pitch spacing, etc. This complexity of seating and space options means that passengers can adopt a brace position in one of several ways, in all cases, the seatbelt should be worn [16].

Several other aviation regulatory bodies such as Transport Canada, CAA U.K, CASA Australia provide guidance to the various brace positions and instructions as to how to attain them. In addition, these instructions often provide specific guidance for specific types of passengers, such as pregnant women or passengers who have physical limitations or space limitations [17].

2) Liveware-Software

Standards and procedures for passenger safety information on the brace position: Safety information for passengers on what to do during an aircraft emergency is normally delivered to passengers in an oral, audio or video pre-takeoff passenger briefing, supplemented by pictograms/pictorials and written information contained in the briefing card placed in each passenger's seat pocket. Delivery of this critical safety information is a mandatory requirement prescribed in Flight Safety Regulations. However, neither the Flight Safety Regulations require the air carriers to inform the passengers about the brace position through the pre-takeoff passenger briefing, nor to include the brace position in the briefing card [18].

As for foreign States, Canada, Australia, U.K require their air carriers to have the brace position included in the briefing card. FAA does not mandate but recommends a practice that the brace position should be included in the briefing card [19].

3) Liveware-Hardware

Passenger inattention to the briefing card: The exact contents and presentation media used for safety briefings and cards are the responsibility of air carriers, as long as the safety information required by the regulators is delivered. Consequently, passenger safety briefings and briefing cards vary depending on air carriers and aircraft types in operation, and NTSB recommendations and research results demonstrate that passenger attention to safety information is waning, and passenger attention to such briefings has been poor at best (Fig.4).

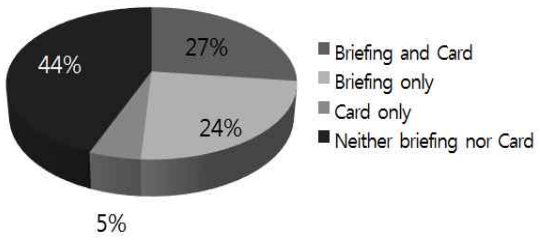

Fig. 4 Percentage of All Passengers Who Indicated Whether or Not They Paid Attention to Safety Information [20]

Passenger incomprehensibility of the briefing card information: Studies have shown that typical passengers, even those who report that they pay attention to briefing cards, have little personal knowledge and understanding of the information they have been given to improve their chances of survival. The studies reveal that passenger comprehension of the briefing card is low: 20 of the 36 pictures on the briefing card were understood by less than 50 percent of the passengers.

These findings were also reflected in survey results from 325 Korean cabin crew members conducted in 2011. For a question about the brace position, most cabin crew members believed that passengers do not know how to adopt the brace position. The reason for this was thought to be the fact that the necessary information is not included in the pre-takeoff passenger briefing and is illustrated only on the briefing card [21]. Similar results have

been found for airline passengers in Canada [22], USA [23] and Australia [24].

One strategy to increase safety knowledge among passengers is to improve the appeal and comprehensibility of the briefing card. While all air carriers have the same or similar briefing card contents in accordance with the requirements specified in Flight Safety Regulations, with regard to the brace position related pictograms/pictorials which are the only source of information for passengers how to react to the aircraft crash impact, there is no provision established.

With the recognition of the problem, though not practiced by Korean air carriers, some foreign air carriers such as Cathay Pacific Airways, Japan Airlines, Qantas, etc. have voluntarily included the brace position in their pre-takeoff passenger safety video briefing. Korean air carriers also need to recognize the necessity to include the brace position in their pre-takeoff passenger briefing.

4) Liveware-Liveware

Brace position instructions for an anticipated/planned landing: In most States, cabin crew members are to be trained in their initial and recurrent training about the brace position for the anticipated/planned emergency landing and the unanticipated/unplanned emergency landing respectively. In the case of an anticipated landing, when time is very limited, cabin crew members normally check and ensure that passengers' seat belts, seat backs and tray-tables are secured. If assumed that there is sufficient preparation time (approximately more than 15~20 minutes), cabin crew members will provide the information orally, accompanied by the pertinent physical demonstration, and will try to check passengers to determine if they can adopt acceptable brace positions (Fig. 5).

Further information is usually given when the aircraft reaches an altitude of 1500 feet, to ensure that the cabin preparation is complete for an emergency landing/ditching. At this altitude, the Captain will order cabin crew members to be seated in their emergency station jump seats. At 30 seconds before touchdown, the Captain will order adoption of the brace position, "Brace! Brace!" and flashing on and off the 'fasten seat belts' signs. Cabin crew members will then keep repeating the order, as loudly and clearly as possible for passengers to adopt the brace position.

> " Ladies and Gentlemen, this is your purser speaking. An emergency situation exists which requires you to follow carefully the instructions given by the cabin crew members. As part of our preparations it will be necessary to move some passengers to other seats. Move to another seat if asked to do so. No smoking, place your seat back in the up position and check your table is secured. Loosen ties and collars. Remove all sharp objects from your clothing, remove dentures, spectacles and high heeled shoes. Stow all articles in the seat pocket in front of you. Now securely fasten your seat belt. Before landing, you will be given the order to brace. Cabin crew will now demonstrate this position. Bend fully forward and place hands behind head. Cabin crew will now demonstrate this position. Bend fully forward and place hands behind head. Keep your feet close to your seat and firmly on the floor. Maintain this brace position so that we can check you. If you have any difficulties tell the cabin crew at this time. Because there may be more than one impact upon landing you are to remain in the brace position until the aircraft comes to a complete stop....."

Fig. 5
Example of Public Address Announcement-Prepared Emergency Landing [25]

Brace position instructions for an unanticipated/unplanned emergency landing: for an unanticipated/unplanned emergency landing, should cabin crew members sense the necessity to adopt the brace position, they will shout verbal commands such as "Bend over! Grab ankles" or "Head down! Stay low!". Unfortunately in such situations, these commands may be difficult, if not impossible, for passengers to understand and follow instantly. First, passengers are not primed to perceive the meaning of these sudden commands. Second, the cabin environment is more likely to be loud and chaotic, with passengers' screaming and noise from the

various falling parts of the aircraft. For passengers to react to these commands and prepare immediately for the imminent impact, there is no other effective way but to include and emphasize the brace position in the pre-takeoff passenger briefing. At present, passengers do not have access to the information on the brace position except by looking at the simple pictograms/pictorials depicted on the briefing card.

3. Results and Conclusions

Though aircraft accident rates have been reduced over the years, due to a heavy transportation volume of air passengers, the number of fatalities in aircraft accidents has not decreased. Most fatalities occur in the crash impact phase. And it has been proven through numerous studies, tests and accident investigation results that passengers who assume the protective brace position sustain significantly less serious injuries than other passengers. Therefore, passengers must be familiarized with the appropriate brace position once on board, and be able to adopt it when facing an emergency landing/ditching situation. Only in the case of an anticipated/ planned emergency landing/ditching with the preparation time allowed, cabin crew members will provide the information via public address system, showing the pertinent demonstration. Most fatal accidents are unanticipated where cabin crew members are not able to give guidance. Thus passengers need to obtain the information through the pre-takeoff passenger briefing, however, all Korean air carriers do not include them in the pre-takeoff passenger briefing, but rather, just have the information depicted as pictorials/ pictograms on their briefing cards. Nonetheless it has been revealed that most passengers do not pay attention to the briefing card. At the moment, there is no standardized regulatory requirement in the Korea Flight Safety Regulations which all the air carriers have to adhere to for their flight operations.

On the basis of these results, the following regulations should be implemented by the regulatory body of the Ministry of Land, Infrastructure and Transport and all the passenger carrying air carriers:

① Korea Flight Safety Regulations Paragraph 8.1.12.4 and Annexed Table 9.3.37 should clearly state that the brace position shall be included in the pre-takeoff passenger briefing or briefing card as seen here in Fig. 6.

Korea Flight Safety Regulations

- 8.1.12.4 Required Passenger Briefings

A. The PIC shall ensure that crew members are aware of the location ~

9. Appropriate brace positions for aircraft crash impact

- Annexed Table 9.3.3.7 Passenger Briefing Cards

A. Air operator certificate holders shall prepare the passenger briefing card in each passenger seat, ~

k) Appropriate brace positions for aircraft crash impact

Fig. 6 Example of New Provisions

② If passengers do not understand the meaning of the pictogrmas/pictorials depicted on the briefing card, there is no purpose of their placements in the passengers' seat pockets. Therefore, Civil Aviation Office needs to have a system in place, wherein the briefing card is tested for passengers' comprehension and supervise the air carriers in this aspect.

③ Air carriers are eventually responsible for the safe travel of their passengers. From this perspective, even before the new provisons are established, it is necessary for Korean air carriers to take a proactive measure to include the brace position in the pre-takeoff passenger briefing, and to have the pictograms/pictorials safety tested for passenger comprehension.

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