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B777 항공기 Final Approach Fix(FAF) 이후 Flight Level Change(FLCH) 사용 이벤트 경향성 분석

Trend Analyses of B777 FLCH Usage Beyond FAF Events

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[요 약]

2013년 7월 아시아나 OZ 214편 샌프란시스코 국제공항 (SFO) 사고의 주요 원인은 조종사의 잘못된 접근 조작과 항공기 오토트로틀 홀드(autothrottle hold) 모드로 인해 자동 속도 컨트롤(control)이 불가함을 인지 못하였고, 복행 (go-around) 결심이 늦었다는 것이다. 이와 관련하여 B777 POM (pilot operation manual)에는 FAF (final approach fix) 후 FLCH (flight level change) 모드 사용을 제한하고 있다. 본 연구는 QAR (quick access recorder) 데이터 분석 시스템을 활용하여 국내 항공사의 B777 기종에서 2년간 발생한 44건의 해당 이벤트를 분석 한 결과, 정상 강하각 보다 높은 위치에서 조종사가 FLCH 모드를 이용하여 급하게 강하하는 과정에서 해당 이벤트들이 주로 발생하였으며, 항공기 베이스 선회 (base Turn) 시 정상 수직 경로(vertical path)보다 낮은 상태에서도 FLCH 모드를 지속 사용한 예도 있었다. 아울러 공항의 표고가 500 ft 이상의 높은 공항에서 이벤트 발생율이 높은 점을 확인하였다. 이에 본연구에서는 항공기 접근 시의 강하 계획(descent planning), 수직 경로(vertical path) 모니터링의 중요성과 자동항법장치 사용 기준 및 안정 접근 항목(stabilized approach criteria)의 준수로 이벤트 경감방안 마련의 시사점을 도출하고자 한다.

[Abstract]

The main causes of the July 2013 OZ 214 accident were poorly performed approach and the failure to recognize the autothrottle in the HOLD position which the automated speed control was not provided. The pilots late decision for go-around was also a critical factor leading to the accident. The B777 POM restricts the use of FLCH mode beyond the FAF. This research utilized the QAR data of an airline's B777 fleet in the period of two years where 44 cases were found. In many cases, the FLCH mode was used for rapid descent from an higher than normal situation. In addition, in the base turn, continuous use of FLCH mode even when the path was below the glide path were observed. Airports with elevation above 500 ft MSL had a higher rate of occurrence. In this research, the proper descent planning and vertical path monitoring, and the adherence to the limitation set in the manuals and the stabilized approach criteria were re-emphasized as mitigation to reduce event occurences.

Key word : A/T hold mode, Base turn, FLCH after FAF, Track mile, Vertical path management.

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I. Introduction

1-1 OZ 214 San Francisco (SFO) Accident

On 6 July 2013, about 1828 UTC, Asiana Airlines Boeing 777-200ER registered HL7742 on a scheduled flight OZ214 from Incheon International Airport(ICN), Seoul, Korea, bound for San Francisco International Airport(SFO), San Francisco, United States, has collided with the seawall, approaching runway 28L in the destination airport. The aircraft was destroyed by the impact and fire. Out of 307 crew and passengers, 3 were killed, and 49 were seriously injured, while 138 suffered minor injuries. The accident occurred in visual meteorological conditions under instrument flight rules flight plan.[1]

The flight was vectored for visual approach to RWY 28L and was instructed to maintain 180 kts until 5 nm from the runway. Following the interception to the final approach course the pilot flying (PF) selected the flight level change speed (FLCH SPD) mode which in order to reduce speed, made the aircraft decrease the descent rate, causing the flight path to diverge above the desired 3° glide path. When the aircraft was about 11.5 nm from the runway, the PF selected the vertical speed (V/S) mode set to -1,000 fpm. The auto throttle (A/T) mode was changed from HOLD to SPD respective to the input. The -1,000 fpm was insufficient to recapture the glide path and upon realization of the high vertical position, the vertical speed was modified to -1500 fpm. Later, the vertical speed was re-set to 1,000 fpm.

When reaching the waypoint DUYET, the MCP altitude was set for 3,000 ft, a standard procedure in preparation for possible go-around, and orders were given for landing configuration. At this time the autopilot mode was switched to FLCH SPD; consequently, the aircraft initiated a climb as the MCP altitude was set to 3,000 ft which was above the aircraft's altitude. The PF disengaged the autopilot and made manual inputs to both flight controls and thrust levers. As the thrust levers were overridden and set to idle, the A/T mode has switched to HOLD; in this mode, the A/T would not control thrust or airspeed. If both flight directors (F/D) had been made off at the same time, the HOLD mode would have switched to SPD, resuming A/T operations however, the pilot monitoring (PM) had left his F/D on. The A/T would remain in HOLD until the decision for go-around.[2]

Figure 1 shows the aircraft altitude and airspeed in the final 40 seconds of the flight. As the aircraft descended below 500 ft above field elevation (AFE), the flight path and airspeed came within the acceptable margin for a short period of time. However, the sink rate was greater than 1,000 fpm and the airspeed was rapidly decreasing.

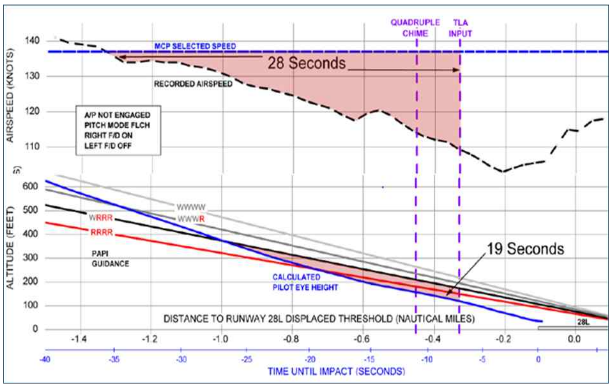


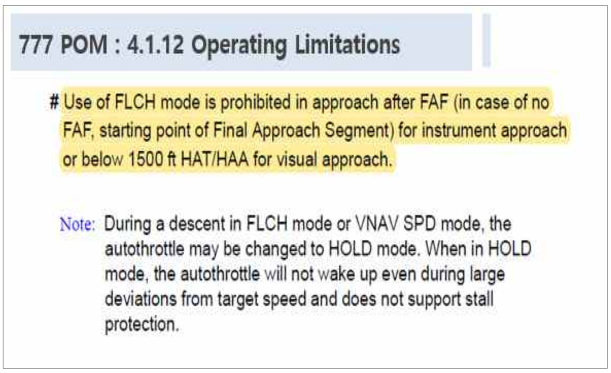
그림 1. 사고 발생 전 40초간 항공기 속도 고도 변화량 (NTSB)

Fig. 1. Profile view of last 40 seconds aircraft accidents (NTSB)

It was at around 200 ft AFE that the crew became aware of the unstabilized state of approach. The go-around however, was not initiated until the aircraft was below 100 ft AFE, at which point performing a successful go-around was unachievable.

1-2 Research Background and Method

According to the K-Airlines B777 pilot operation manual (POM) regarding the operation limitations of the autopilot flight director system (AFDS), the use of FLCH mode is prohibited in approaches beyond the final approach fix (FAF) for instrument approaches; when FAF does not exist, starting point of final approach segment; and for visual approaches, below 1500 ft height above terrain (HAT)/height above airport (HAA). It is also noted that during a descent in the FLCH or the vertical navigation speed (VNAV SPD) mode, the A/T mode may be changed to HOLD. As mentioned previously, in the HOLD mode the protection against limitation speeds and deviations from target speeds is not provided.[3]



777 POM : 4.1.12 Operating Limitations

Use of FLCH mode is prohibited in approach after FAF (in case of no FAF, starting point of Final Approach Segment) for instrument approach or below 1500 ft HAT/HAA for visual approach.

Note: During a descent in FLCH mode or VNAV SPD mode, the autothrottle may be changed to HOLD mode. When in HOLD mode, the autothrottle will not wake up even during large deviations from target speed and does not support stall protection.

그림 2. B777 POM - FAF 이후 FLCH 사용 제한

Fig. 2. B777 POM - restriction of FLCH mode beyond the FAF

- ✓ **Date Period : 2017 4Q ~ 2019 3Q (2 Years)**
  - Total Operating FLTs : 88,351 FLTs
- ✓ **Event Definition**
  - Limitation : Pitch Mode FLCH maintained after FAF
  - Duration : More than 5 seconds

그림 3. 이벤트 Data 분석 기간 및 정의
Fig. 3. Event data analysis period & definition

Although the POM clearly stated the restriction on the usage of FLCH during final approaches, several cases were discovered in a flight operation quality assurance (FOQA)[1)] analysis in the 3rd quarter of 2019; 6 cases were found to have used FLCH beyond the FAF resulting in excessive descent rate. The use of FLCH beyond the FAF poses similar potential threat of airspeed mismanagement as that of the Asiana flight OZ214 accident. The possibility of divergence between the autopilot mode and the pilot's expectation is considered a hazard.[4]

In order to identify such hazards in flight, the airline decided to have a thorough review of all the flights in the previous two years; 4Q of 2017 to 3Q of 2019, where over 88,000 flights were reviewed. As shown in figure 3, the hazard was newly created as a FOQA event. The event was defined as the usage of FLCH mode beyond the FAF for over 5 seconds.

In order to search for such cases, the quick access recorder (QAR) data were analyzed. The trend per time period/airport, the duration(or distance traveled within the event) of the events, and vertical flight path were analyzed in order to identify and remove potential hazards and causual factors to reduce the occurrences and promote safety of flight.[5]

II. B777 Autopilot Flight Director System (AFDS) & Autothrottle(A/T)

The B777 AFDS and the autothrottle provide automatic pitch, roll, and thrust controls respective to the mode selected by the pilot. The AFDS may be manipulated via the mode control panel (MCP) and the flight management computer (FMC). The AFDS pitch and autothrottle modes are summarized in tables 1 and 2, respectively.

1) FOQA (Flight Operation Quality Assurance) : Proactive safety program operated by the operator to monitor the QAR data insuring safety in flight.

표 1. AFDS 피치 모드
Table 1. Selected AFDS Pitch Modes

AFDS Pitch Mode	AFDS Annunciation	AFDS Pitch Mode Description
Flight Level Change Speed	FLCH SPD	Acquires and maintains the MCP airspeed target by changing the pitch in a given power setting
Vertical Speed	V/S	Acquires and maintains an MCP vertical speed target
Takeoff/Go-Around-Pitch	TO/GA	Acquires and maintains takeoff speed reference after liftoff, or go-around speed reference after initial go-around rotation
Vertical Navigation Speed	VNAV SPD	Follows vertical steering commands from the FMC. VNAV SPD acquires and maintains an FMC or MCP speed target.

표 2. Autothrottle 모드
Table 2. Autothrottle Mode

A/T Mode	A/T Annunciation	A/T Mode Description
Thrust Reference	THR REF	Thrust set to the reference thrust limit displayed on EICAS
Speed	SPD	Thrust applied to maintain target airspeed set using the MCP or FMC
Thrust	THR	Thrust applied to maintain the climb/descent rate required by AFDS pitch mode
Idle	IDLE	The A/T controls the thrust levers to the aft stop
Hold	HOLD	The A/T removes power from the servo motors. In this mode, the A/T does not move the thrust levers
No Mode		A/T is armed but not engaged. This is the only state where the A/T automatic engagement function is potentially active

When in FLCH SPD mode, the A/T mode switches to IDLE followed by HOLD mode. The HOLD mode may also occure when the pilot overrides the thrust levers. In the HOLD mode, thrust lever servos are inhibited and the autothrottle does not control thrust or speed. Thrust levers can be manually advanced.[6]

III. Occurrence Trend of FLCH Usage Beyond the FAF

3-1 Event Quick Assess Recorder (QAR) Analysis

The QAR is a device that records the flight data. The type of data collected includes the pilots' inputs in the flight controls, airspeed, altitude, sink rate, A/P mode, thrust setting, etc. The system is designed to be easily accessible for quick download. The data is downloaded through a storage medium or by wireless communication when the aircraft arrives at the home base airport. The data collected is analyzed in the FOQA system. The analysis of a flight (or an event) is done with consideration to other information such as the landscape, weather, instrument approach used etc. The regular and periodical analysis of the QAR data provides the trend in event occurrences, and are used for proactive identification of hazards, improving the safety of flight.[7]

표 **3.** QAR data 분석
Table 3. QAR data analysis

FLAP			ROLL mode	PITCH mode	DTG		IAS	IAS	GS	ALT	ALT	RA	HAT	IVV
LEVER	ANGLE	VFE			NM/S	NM	kts	SEL	kts	SEL	Baro	feet	feet	fpm
30	29	180	LOC	FLCH SPD	0.05	3.78	163	158	163		3680	1918	1541	-1728
30	**30**	180	LOC	**FLCH SPD**	0.05	**3.74**	156		162	1600	3651	**1907**	1512	**-1736**
30	30	180	LOC	FLCH SPD	0.04	3.69	158	158	161		3622	1869	1483	-1768
30	30	180	LOC	FLCH SPD	0.04	3.65	155		161	1600	3592	1858	1453	-1856
30	30	180	LOC	FLCH SPD	0.04	3.60	157	147	160		3562	1843	1423	-1928
30	30	180	LOC	FLCH SPD	0.04	3.56	159		160	1600	3530	1789	1391	-1976
30	**30**	180	LOC	**FLCH SPD**	0.04	**3.51**	156	147	159		3497	**1727**	1358	-2152
30	30	180	LOC	FLCH SPD	0.04	3.47	156		159	1600	3462	1672	1323	-2240
30	30	180	LOC	FLCH SPD	0.04	3.43	158	147	158		3424	1638	1285	-2296
30	30	180	LOC	FLCH SPD	0.04	3.38	157		158	1600	3386	1595	1247	-2344
30	30	180	LOC	FLCH SPD	0.04	3.34	156	147	157		3347	1551	1208	-2344
30	30	180	LOC	FLCH SPD	0.04	3.29	156		157	1600	3308	1499	1169	-2344
30	30	180	LOC	FLCH SPD	0.04	3.25	156	143	156		3268	1434	1129	-2312
30	30	180	LOC	FLCH SPD	0.04	3.21	154		156	1600	3230	1399	1091	-2352
30	30	180	LOC	FLCH SPD	0.04	3.16	157	143	156		3191	1381	1052	-2368
30	30	180	LOC	FLCH SPD	0.04	3.12	154		155	1600	3152	1374	1013	-2360
30	30	180	LOC	**G/S**	0.04	3.08	153	143	155		3112	**1371**	973	-2336
30	30	180	LOC	G/S	0.04	3.04	154		154	1600	3073	1339	934	-2264
30	30	180	LOC	G/S	0.04	2.99	153	143	154		3035	1314	896	-2160
30	30	180	LOC	G/S	0.04	2.95	154		153	1600	2998	1272	859	-2000
30	30	180	LOC	G/S	0.04	2.91	151	143	153		2965	1251	826	-1696

Table 3 is an example of a QAR data analysis. The data is from a 'descent rate high & FLCH use beyond the FAF event' that occurred at the instrument landing system (ILS) approach to Campinas International Airport (VCP), São Paulo, Brazil. The field elevation of the airport is 2170 ft mean sea level (MSL), and the FAF is located 6.1 nm from the runway at 3,820 ft MSL. The flight maintained the FLCH mode until 3.1 nm from the runway, peak sink rate was recorded at 2,344 fpm, becoming marked as a FOQA event.

3-2 Event Occurrence by Quarter

During a period of two years between 2017 4Q to 2019 3Q, more than 88,000 flights has been analyzed where a total of 44 cases were found to have used the FLCH mode beyond the FAF.2) The average occurrence was 5.5 per quarter. The 3Q of 2018 had the highest number of cases at 11, where 8 cases occurred in the approach to ICN, 2 in Vienna International Airport (VIE), and 1 in Hong Kong International Airport (HKG).

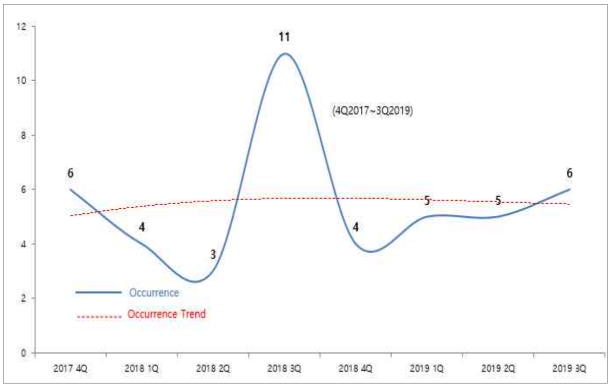


그림 **4**. B777 FAF 이후 FLCH 사용 이벤트 현황 (2017-2019)
Fig. 4. B777 FLCH usage event status (2017-2019)

2) “B777 FLCH usage after FAF trend ” special analysis report, Company Internal SMS Meeting (2019)

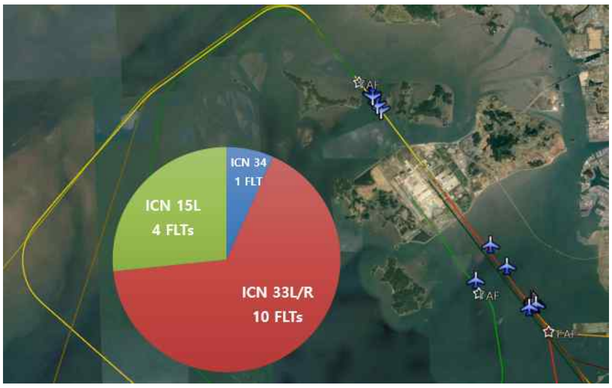


그림 **5.** 인천공항, FAF 후 FLCH 이벤트 사례
Fig. 5. ICN airport, FLCH after FAF event case

3-3 Event Occurrence by Airport

In ICN, 11 cases were found to have misused the FLCH beyond the FAF for RWY 33 and 34. 4 cases were found for RWY 15. The captain (CPT) flying was 8 and the first officer (FO) flying was 7.

Out of the 15 cases, 14 occurred while in a steep descent from a higher-than-normal vertical path. As shown in Table 4, 3 cases had the glideslope (G/S) capture done at around 1,000 ft HAT, 3nm from the runway. The airline's flight operations manual (FOM) clearly states that the aircraft must be in landing configuration and on a stabilized approach by 1,000 ft HAT in the instrument meteorological conditions (IMC), and by 500 ft HAT in the visual meteorological conditions. The importance of stabilized approach is emphasized.

Although the number of cases in ICN far exceeds other airports, the cases per 10,000 flights as shown in figure 6, indicate that the rate of occurrence is lower than other airports.

표 **4.** 인천공항 FAF 후 FLCH 이벤트 분석
Table 4. ICN airport, FLCH after FAF event analysis

RWY	MCP ALT SET (ft)	FLCH Maintain ALT(ft)	FLCH Maintain Distance(NM)	G/S Capture	G/S Captured Distance(NM)	LDG CONF Completed ALT(ft)	LDG CONF Completed Distance(NM)
ICN 33R	1400	2224	6.5	2201	6.5	1511	4.5
ICN 33R	1000	2146	6.5	2102	6.5	1436	4.4
ICN 33R	6000	2289	6.3	2266	6.3	1210	3.6
ICN 15L	**700**	**1186**	**3.3**	**1138**	**3.3**	1987	5.9
ICN 33R	1000	2064	6.6	2017	6.6	1436	4.5
ICN 15L	**1100**	**1404**	**4.3**	**1381**	**4.3**	1973	5.3
ICN 34	**0**	1555	4.3	1504	**4.3**	1761	5.3
ICN 33R	300	1187	3.3	1138	3.2	2216	5.1
ICN 33R	1200	2241	6.7	2163	6.6	1520	4.5
ICN 33R	1000	2242	6.6	2193	6.6	1173	3.5
ICN 33L	1500	2256	6.6	2212	6.6	1757	5.2
ICN 33R	1600	2197	6.9	2153	6.8	1738	5.5
ICN 33R	1000	1564	4.6	1423	4.4	1858	5.3
ICN 15L	**1900**	**1046**	**2.9**	**1005**	**2.9**	1828	5.3
ICN 15L	**1100**	**1601**	**4.4**	**1330**	**3.9**	1747	4.9

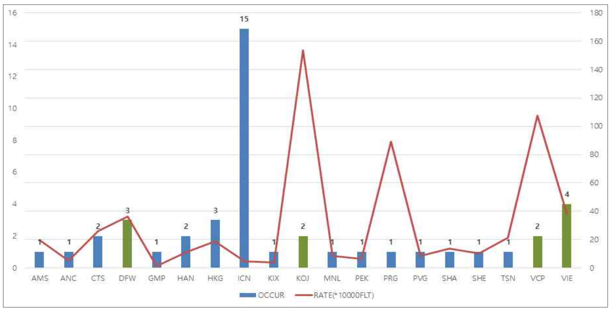


그림 6. 공항별 이벤트 발생 현황
Fig. 6. Event occurrence by airport

The two cases of VIE were due to prolonged use of FLCH mode while the aircraft was turning base, resulting the aircraft positioning below G/S. The one case of HKG was due to the delay in arming the ILS approach mode. The aircraft ended -2.64 dots below the G/S. The three cases indicate that human error is a dominant cause of the events.

The airport data shown in green in figure 6 indicate airports with elevation above 500 ft MSL. A total of 11 cases were found to be from high elevation airports, consisting 25% of the 44 total cases. This indicate that the approach to high elevation airport require more attention from the pilots to maintain proper vertical path.

3-4 Event Occurrence by B777 aircraft type and PF

When the cases are broken down by the type of B777 aircraft, data has shown that the B777F has a higher rate of occurrence compared to its passenger counterpart. Figure 7 shows the event number and occurrence rate per aircraft type. The passenger flights dominate in numbers at 29 cases compared to 15 however, the occurrence rate in the B777F is far greater. The cargo flights are less frequent compared to the passenger flights, are routed to unfamiliar airports exposing the pilots to more workload, and are mostly done at night time, increasing the chance of fatigue, leading to higher risk of human error.

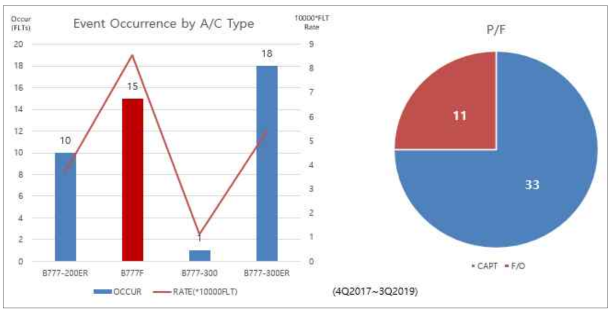


그림 7. 항공기 &, PF 별 이벤트 발생 현황
Fig. 7. Event occurrence by aircraft type and PF

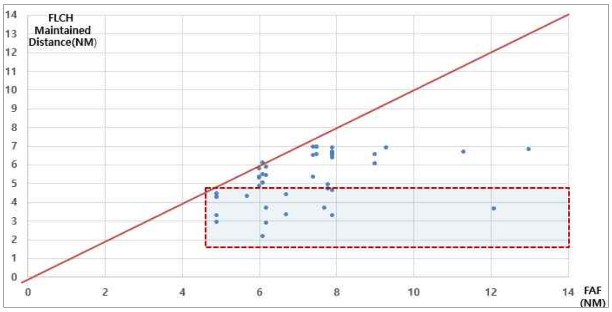


그림 8. FAF 통과 후 FLCH 유지 거리
Fig. 8. FLCH maintained distance after passing FAF

When the data is analyzed by the PF, 33 cases were from CPT, and 11 from FO. The CPT's normally take controls in flights with known hazards such as unfamiliar airports, bad weather etc., therefore have a greater sample compared to that of the FO's. Figure 7 shows the events broken down by aircraft type and the pilot flying.

IV. Event Maintained Distance & Vertical Path Analysis

4-1 FLCH Maintained Distance

The vertical axis in figure 8 is the remaining distance from the runway that the FLCH mode was maintained. The horizontal axis is the distance of the FAF from the runway. For example, the case positioned in the bottom right part of the dotted box means that the FAF was 12.1 nm from the runway however, the FLCH mode was maintained until when the aircraft was 3.8 nm from the runway.

The red line indicates the limit to which the FLCH may be used; or the distance from the runway to the FAF. In normal cases where the FLCH mode is disengaged before reaching the FAF, the coordinates would be positioned above the red line. The vertical distance from the red line indicates the distance traveled with the FLCH mode set. As highlighted by the dotted box, 17 cases were found to have had the FLCH mode maintained even after the aircraft was less than 5 nm from the runway.

4-2 Event Vertical Path Analysis

1) G/S Capture from Above

B777 POM states that when intercepting G/S from above, flight crew should attempt to capture the G/S prior to the FAF.[3]

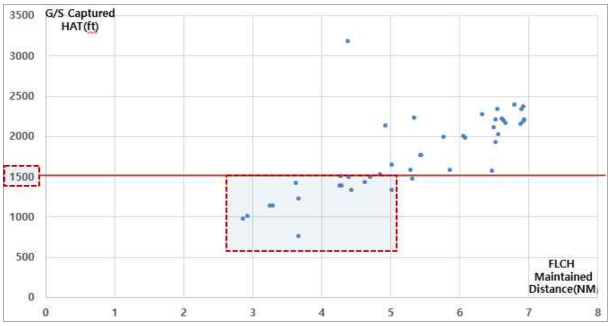


그림 9. FLCH 유지 거리 및 G/S capture 고도
Fig. 9. FLCH maintained distance & G/S capture altitude

그림 10. V/S 모드 이용한 G/S 인터셉트
Fig. 10. V/S mode intercepting G/S

Out of the 44 discovered cases, 26 or 35% of the cases were above G/S. 15 or 34% of the cases were found to have captured the G/S past the FAF and below 1,500 ft AFE. The distances left to the runway were less than 5 nm.

According to the airline's POM 5.9.2, the procedure for capturing the G/S from above is by setting an altitude higher than aircraft altitude in the MCP and selecting the V/S mode for -1,500 fpm.[3] Figure 10 shows that out of the 26 above G/S cases, 9 utilized the V/S mode, where only 1 case actually complied with the procedure for capturing the G/S from above. In three cases, the MCP altitude was captured, increasing the already above G/S deviation; the pilot used the FLCH mode in order to capture the G/S even when the aircraft was already beyond the FAF.

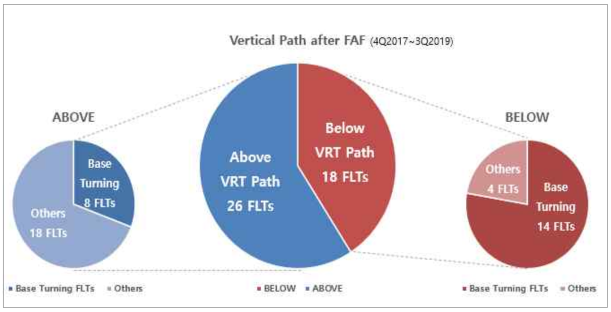


그림 11. FAF 이후의 vertical path
Fig. 11. Vertical path after FAF

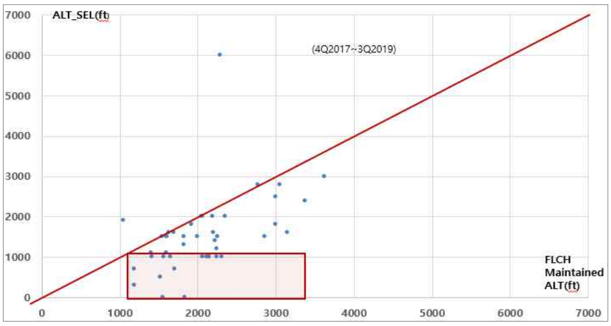


그림 12. FLCH 사용 시 MCP & 최저 고도
Fig. 12. MCP & minimum altitude with FLCH

2) Below G/S Cases

While 26 cases were above G/S, 18 were below but still maintained the FLCH mode beyond the FAF. It was found that almost 80% of such cases have occurred while turning base as shown in figure 11. In a straight in approach, the pilots only needs to consider vertical profile and airspeed however, when turns are involved, the lateral track also needs to be considered. The track mile calculation becomes more difficult than that of straight in approaches. Therefore, the turn to base have increased the workload of the pilots. It can be assumed that the pilots were fixed in the lateral track that they left the FLCH mode even after descending below the proper flight path.

4-3 Aircraft Manipulation

1) MCP altitude with FLCH usage

The FLCH mode for descent requires that a lower altitude be set on the MCP panel. The MCP altitude set for the 44 cases were analyzed. The vertical axis in figure 12 is the altitude set and the horizontal axis is the lowest level reached via the FLCH mode. In 15 cases, the pilots have set an altitude lower than 1,000 ft where 2 cases were found to have had the MCP set at 0 ft. This is a potential hazard as the FLCH mode provide no terrain avoidance. The two cases with coordinates above the red line are set to higher altitude as the flight was transitioned to manual flight.

2) Landing Configuration Altitude with FLCH

The flight operations manual (FOM) requires that the landing configuration must be set by 1,500 ft HAT when in a precision approach.[8] Figure 13 shows the correlations between the landing configuration completed altitude and the FLCH mode disengagement altitude. Around 75% of the cases show that the configuration for landing was completed after the FLCH mode was disengaged. This suggest that the pilot's attention was more focused to the G/S capture.

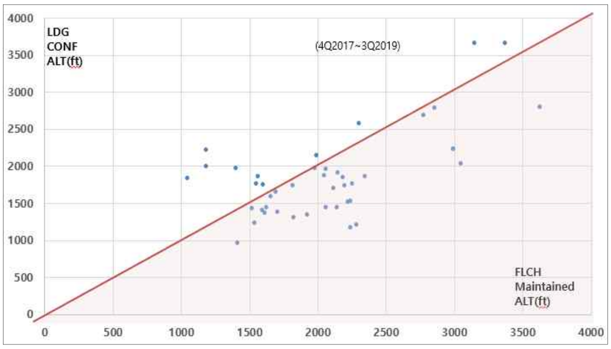


그림 **13.** FLCH 사용 시 착륙 외장 완료 고도
Fig. 13. Landing configuration altitude with FLCH

V. Conclusion

This research looked into the probable causes of the fatal accident of Asiana flight OZ214, mismanagement of descent during the approach, unintended deviation of automatic airspeed control due to the A/T HOLD mode, delayed execution of a go-around in unstabilized approach conditions, to assess hazards that may exist in the flight operations. QAR data from over 88,000 flights in the period of two years was analyzed to find the use of FLCH mode beyond the FAF. The research discovered a total of 44 cases that had maintained the FLCH mode beyond the FAF. The trend and recommended implications are as follows.

11 cases were found to have taken place at high elevation airports of over 500 ft MSL. This is 25% of the discovered cases, but when converted to rate of occurrence, the high elevation airports clearly showed a higher occurrence rate. The pilots' vertical path awareness is especially emphasized when flying into high elevation airports.

The B777 POM requires that when intercepting the G/S from above, the G/S should be captured prior to reaching the FAF however, cases were discovered where the FLCH mode was used to create high rate of descent in order to capture the G/S. 26 flights had captured the G/S from above while 18 from below. In the 18 cases, the pilots continued the use of FLCH mode after the FAF and below the G/S. 80% of the below G/S cases occurred while in base turn. As the trackmile calculations are more difficult in base turns, workload is increased. The adherence to the proper procedures and proper descent planning is emphasized.

The Cargo flights showed a higher occurrence rate compared to its passenger counterparts. The cargo flights are usually done at night time increasing the chance of fatigue, and often to unfamiliar destinations exposing the pilots to higher workload.

The landing configuration must be planned to be completed by 1,500 ft HAT however, 30% of the cases had the configuration set below 1,500 ft HAT. Landing configuration is one of the critical factors in stabilized approach therefore must be properly planned and executed.

The flight crew must be fully aware of the stabilized approach criteria and comply with the set regulations. If the PF fails to maintain proper flight track, airspeed, sink rate etc., the PM must actively callout such deviations and go-around as necessary. Such communication should be maintained throughout the approach and landing.[9] In any way the flightcrew must avoid unstabilized conditions.

The research is limited to the 2 years record of flights from a single airline in Korea. Future research calls for the integrated data set of all the flight records collected through the national level of safety management program.

References

[1] Accident report, descent below visual glidepath and impact with seawall Asiana Airlines flight 214 Boeing 777-200ER HL7742 San Francisco California, national transportation safety board, Washington, D.C. NTSB/AAR-14/01, pp. 19-27, Jun. 2014.

[2] The aviation herald, accident: Asiana B772 at San Francisco on Jul 6th 2013, touched down short of the runway, broke up and burst into flames, [Internet] available : http://avherald.com/h?article=464ef64f&opt=4096

[3] K airline, ERP pilot operation manual [Internet]. available: http://erp.koreanair.com

[4] S. S. Silva, and R. J. Hansman, "Divergence between flight crew mental model and aircraft system state in auto-throttle mode confusion accident and incident cases," *Journal of cognitive engineering and decision making,* Vol. 9, No. 4, pp. 312-328, Sep. 2015

[5] ICAO, Doc 10000, Manual on flight data analysis programmes (FDAP), pp. 1.3-1.4, 1st ed. 2014.

[6] K airline, ERP flight crew operation manual [Internet]. available: http://erp.koreanair.com

[7] Federal aviation administration, advisory aircular 120-82, flight operational quality assurance, pp. 1-25, 2004.

[8] K airline, ERP flight operations manual [Internet]. available: http://erp.koreanair.com

[9] T. Blajev, and Capt. W. Curtis, *Go-around decision-making and execution project*, flight safety fondation, pp. 32, 2017

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