AA2019-5

AIRCRAFT ACCIDENT
INVESTIGATION REPORT

KOREAN AIR LINES CO., LTD.
H L 7 7 2 5

June 27, 2019

JTSB Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board and with Annex 13 to the Convention on International Civil Aviation is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Nobuo Takeda
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT ACCIDENT INVESTIGATION REPORT

DAMAGE ON LOWER AFT FUSELAGE
DUE TO TAIL STRIKE DURING GO-AROUND
KOREAN AIR LINES CO., LTD.
BOEING 737-900, HL7725
ON RUNWAY 06L AT KANSAI INTERNATIONAL AIRPORT
AT AROUND 21:33 JST, APRIL 09, 2018

May 24, 2019
Adopted by the Japan Transport Safety Board
Chairman Nobuo Takeda
Member Toru Miyashita
Member Yoshiko Kakishima
Member Yuichi Marui
Member Yoshikazu Miyazawa
Member Miwa Nakanishi

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident	On Monday, April 9, 2018, a Boeing 737-900, registered HL7725, operated by Korean Air Lines Co., Ltd., suffered damage on the lower aft fuselage when making a go-around after a bounced landing on runway 06L at Kansai International Airport at around 21:33 JST. There were 99 people in total on board, consisting of the PIC, seven other crew members, and 91 passengers. No one was injured.
1.2 Outline of the Accident Investigation	On April 10, 2018, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two investigators to investigate the accident. An accredited representative and an adviser of the Republic of Korea, as the State of the Registry and the Operator, and an accredited representative of the United State of America, as the State of the Design and Manufacture of the aircraft involved in the accident, participated in the investigation. Comments were invited from the parties relevant to the cause of the accident and the Relevant States.

2 FACTUAL INFORMATION

2.1 History of the Flight

According to the statements of the Captain and the first officer (hereinafter referred to as "the FO"), the records of the flight data recorder (FDR) and the cockpit voice recorder (CVR), and the records of ATC communications, the flight history was summarized below.

At 20:24 Japan Standard Time (JST: UTC+9 hours, unless otherwise stated in this report all times are indicated in JST on a 24-hour clock), on April 9, 2018, Boeing 737-900, registered HL7725 operated by Korean Air Lines Co., Ltd. (hereinafter referred to as "the Company"), as the Company's scheduled Flight 733, took off from Jeju International Airport (the Republic of Korea) bound for Kansai International Airport (hereinafter referred to as "the Airport"). The Captain sat in the left seat as PF[*1] and the FO sat in the right seat as PM[*1].

The landing briefing commenced at around 20:59 prior to the descent did not include information regarding a tailwind at the time of the landing.

The aircraft was instructed to fly directly to BERRY (see Figure 1) via NALTO when descending the route prescribed in the standard instrument arrival. The aircraft was descending with receiving a tailwind. The wind at an altitude of 4,000 ft where the Aircraft started the final approach on the ILS approach for runway 06L of the Airport was about 20 kt in tailwind. The wind information (see 2.5(1)) provided by an air traffic controller (hereinafter referred to as "the Controller") of the Airport after the aircraft had passed over BERRY was 030 ° in wind direction and 30 kt in wind velocity. Both the auto-pilot and the auto-throttle of the aircraft were disengaged at around a radio altitude of 1,200 ft. In addition, the aircraft continued a stabilized approach in the tailwind afterwards, and it was about 5 kt tailwind at an altitude of 1,000 ft in the Captain's memory. The Captain, who was assuming that a landing would be made in the tailwind, planned to put the thrust levers to their idle position earlier than usual with performing a flare (nose up maneuver to reduce the

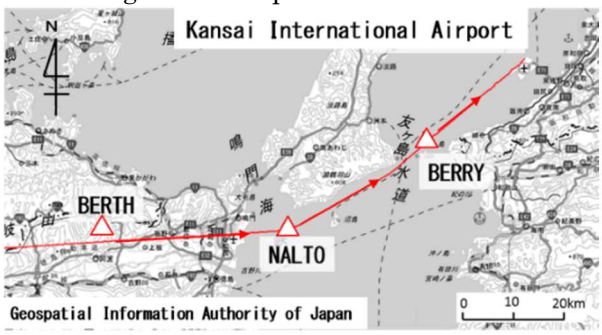


Figure 1 ; Estimated Flight Route before Go-around

[*1] PF (Pilot Flying) and PM (Pilot Monitoring) are terms used to identify pilots with their roles in aircraft operated by two persons. The PF is mainly responsible for maneuvering the aircraft. The PM mainly monitors the flight status of the aircraft, cross checks operations of the PF, and undertakes other non-operational works.

rate of descent) in order to prevent that a touchdown would be long down on the runway. The Captain memorized that the wind information provided by the Controller along with issuing the landing clearance had been 3 kt in crosswind (in fact, wind direction was 030 º and wind velocity was 3 kt) and also stated that the wind at the vicinity of the runway threshold had been almost calm.

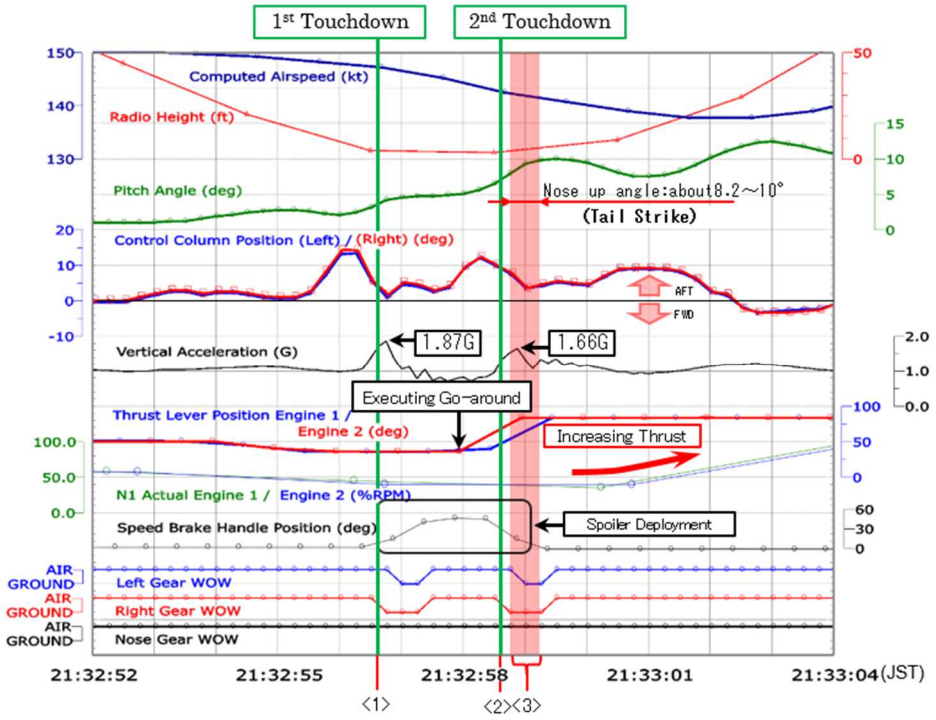
The FO was feeling that the approach was stabilized, except that the engine thrust of the aircraft had been set lower than usual. The FO thought the stabilized approach would continue afterward because the captain had set the normal engine thrust after the auto-call of a radio altitude of 100 ft.

At around 21:32:54, the Captain moved the thrust levers to their idle position along with initiating the flare at 2 º pitch angle at a radio altitude of about 30 ft. Although the captain tried to continue raising the nose and to reduce the rate of descent, the timing of such maneuvers was slightly delayed from the captain's assumption. Reducing the rate of descent was infeasible because the thrust levers had already been set to their idle position. The Captain tried to reduce the rate of descent of the aircraft by pulling the control column further.

The FO felt that the amount of the flare the Captain was operating was somewhat small. The FO, who felt that the intervals of the auto-call made at every 10 ft at a radio altitude of 30 ft or below were short and the rate of descent was large, pulled the control column to reduce the rate of descent without making any call-out. Having noticed the operation of the FO, the captain kept the control column so as to follow the FO's operation.

At around 21:32:57, the right main landing gear of the aircraft touched down at pitch angle of about 3.5 º (Fig. 2 <1>), and all spoilers began to deploy when the auto speed brake was activated. Subsequently, after the left main landing gear had touched down, the aircraft bounced. The maximum vertical acceleration recorded in the FDR during this period was 1.87 G.

The captain, who was unable to predict the degree of the bounce and assumed that the impact accompanied by the touchdown after the bounce would be hard, executed a go-around maneuver. The pitch angle of the aircraft immediately before executing the go-around was about 5 º. The aircraft started climbing positively at about 10 ° pitch angle after its both main landing gears touched down again (Fig.2<3>) from its right main landing gear at about 7 ° pitch angle (Fig.2<2>) approximately one second after it had executed the go-around (approximately two seconds after its right main landing gear made a first touchdown). The Captain

	recognized that the FO was controlling the movement of the control column though the Captain had no memory of the pitch angle in this period. The FO came to notice that the pitch angle was high, and tried to ~~control~~ the movement of the control column uttering something to the Captain, however, the FO did not remember when he did so. Moreover, CVR did not verify the words the FO claimed to have uttered to the Captain. The aircraft landed on runway 06L conducting the ILS approach again after flying in accordance with the missed approach procedure. Both the PIC and the FO did not recognize that the aircraft had struck the runway until the scratch marks were found on the lower aft fuselage by mechanics after the aircraft arrived at the allotted parking spot.  Figure 2 ; FDR Data This accident occurred on runway 06L (34° 25' 52" N, 135° 12' 36" E) of Kansai International Airport at around 21:33 on April 9, 2018.
2.2 Damage to the Aircraft	Substantial damage (1) Lower aft fuselage: Scratch marks (2) Tail Skid*2: Damaged (see Figure3)
2.3 Personnel Information	(1) PIC Male, Age 45 Airline transport pilot certificate(Airplane) January 26, 2011

*2 "Tail Skid" means the equipment to prevent or reduce damage on an aircraft caused by a lower aft fuselage striking a runway as a result of an excessive nose up during a take-off and a landing.

	Type rating for Boeing 737 June 27, 2017 Class 1 aviation medical certificate Validity May 31, 2018 Total flight time 5,893 hours 05 minutes Flight time in the last 30 days 30 hours 07 minutes Total flight time on the type of the aircraft 216 hours 00 minutes Flight time in the last 30 days 30 hours 07 minutes (2) FO Male, Age 33 Commercial pilot certificate (Airplane) June 22, 2012 Type rating for Boeing 737 November 01, 2016 Instrument rating September 11, 2012 Class 1 aviation medical certificate Validity January 31, 2019 Total flight time 1,796 hours 01 minutes Flight time in the last 30 days 46 hours 57 minutes Total flight time on the type of the aircraft 792 hours 12 minutes Flight time in the last 30 days 46 hours 57 minutes
2.4 Aircraft Information	(1) Aircraft Type: Boeing 737-900 Serial number: 29999 Date of manufacture: May 11, 2004 Certificate of airworthiness: AS05106 Validity Not specified Category of airworthiness: Airplane Transport (T) Total flight time 30,740 hours 29 minutes (2) At the time of the accident, the weight of the Aircraft is was estimated to have been 128,926 lbs, and the position of the center of gravity is estimated to have been 19.6% MAC[*3] , accordingly, both of which stayed within the allowable range.
2.5 Meteorological Information	Aeronautical weather observations at the relevant time of the accident at the Airport (wind direction and wind velocity) were as follows. Note: The prevailing visibility was 10 km or more, the amount of cloud was 1/8-2/8 and the height of cloud base was 3,000 ft at each observations time as stated in the table below. Table1 ; Wind direction and wind velocity at the relevant timeof the accident

Observation time	20:30	21:00	21:30
Wind direction(°)	140	050	010
Wind velocity(kt)	03	03	03

[*3] "MAC" stands for Mean Aerodynamic Chord, meaning a chord that represents the aerodynamic characteristics of a wing. It is the representative chord length if the chord is not constant as in the case of a sweptback wing. 19.6% MAC indicates a position located at a distance of 19.6% from the leading edge of the mean aerodynamic chord.

Besides, wind direction and wind velocity shown in the above table were observed by a 2-minute average anemometer installed about 450 m beyond the threshold of runway 06L and about 150 m north of the runway centerline. The data observed at the time of the accident did not show any significant change in wind direction and wind velocity. In addition, the Controller provided the aircraft with the wind information obtained from this anemometer.

(2) According to the Significant Weather Observation Chart (RJBB) at 21:00 on the day of the accident and was issued at 21:11 on the same day, wind direction and wind velocity in the sky over the Airport were as follows.

Table2 ; Wind direction and wind velocity in the sky over Kansai International Airport

Altitude(ft)	Wind direction(°)	Wind velocity(kt)
18,000	290	64
10,000	290	40
5,000	250	21
2,500	270	09

2.6 Additional Information

(1) Damage on the aircraft

Scratch marks approximately 210 cm in length and approximately 36 cm in the maximum width were found on the skin of the lower aft fuselage including cracks.

In addition, the tail skid was broken.

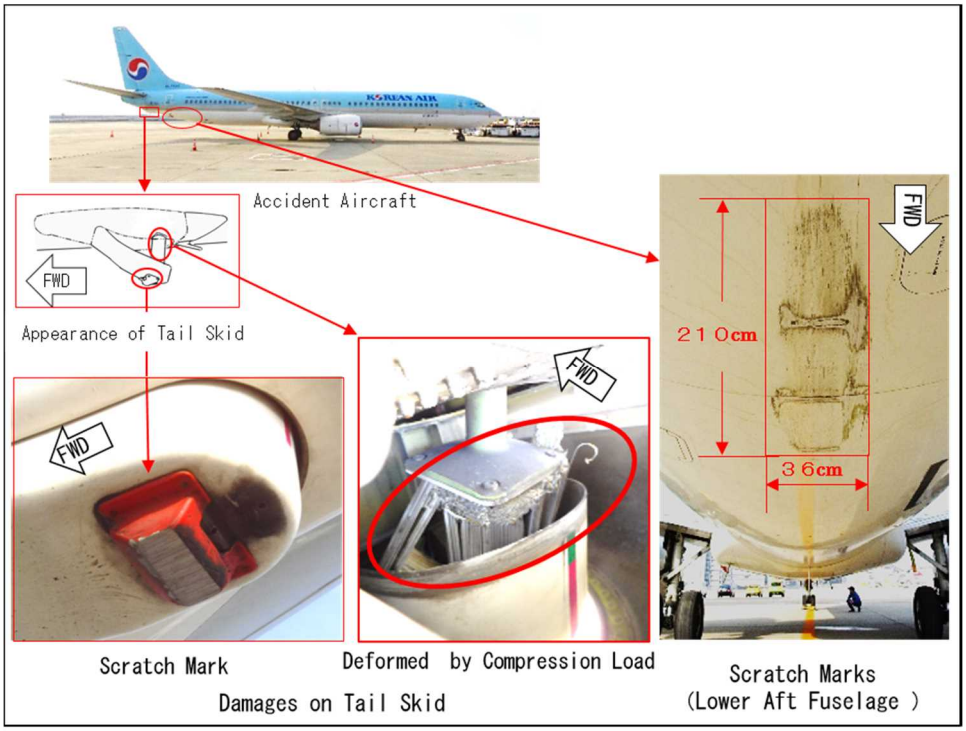


Figure 3 ; Damages on the Aircraft

(2) Accident Site

Kansai International Airport has two runways of 06R/24L (3,500 m in length and 60 m in width) and 06L/24R (4,000 m in length and 60 m in width).

On-site investigation found the scratch marks approximately 15 m in length and approximately 30 cm in the maximum width on a location about 445 m beyond the threshold of runway 06L.

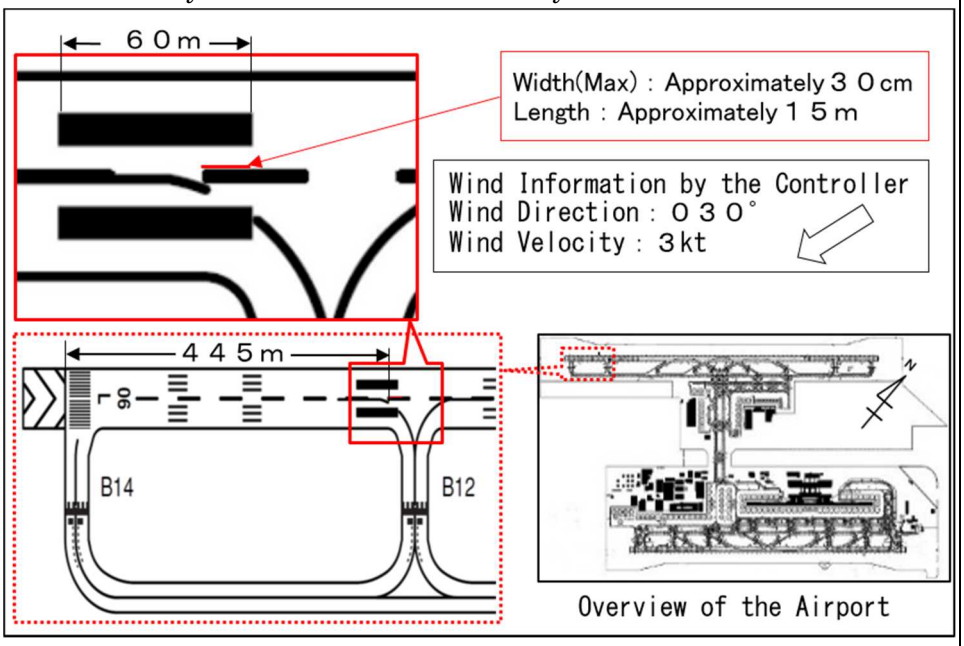


Figure 4 ; Accident Site

(3) Landing Flare Profile of the Same Type of the Aircraft

The Flight Crew Training Manual (FCTM), which contains such information as operational techniques recommended by a manufacturer of aircraft and is accepted by the Federal Aviation Administration (FAA), prescribes regarding the landing of the same type of the aircraft as outlined below.

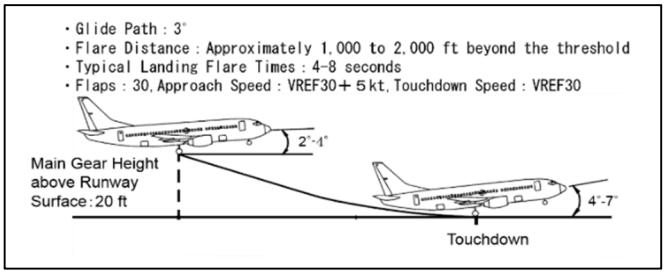


Figure 5 ; Landing Flare Profile of Same Type of Aircraft (FCTM)

- Reduce the rate of descent by increasing pitch attitude by approximately 2 ° - 3 ° when the main gear height reaches about 20 ft above the runway surface.
- After initiating the flare, smoothly retard the thrust levers to idle, and make small pitch attitude adjustments to maintain the desired rate of descent.
- Hold the control column by the sufficient back pressure required to

keep the pitch attitude constant.

• Set the thrust levers to idle position almost simultaneously with touching down of the main gears.

(4) Bounced Landing

Advisory Circular (AC) 120-114: Pilot Training and Checking/3.10.10 Recovery From a Bounced Landing/3.10.10.2 Awareness Criteria published by the FAA describes that an excessive descent rate, a late flare initiation, an incorrect flare technique and others could be caused of bounced landing.

(5) Bounced Landing Recovery

The Pilot Operating Manual (POM) and the training guide issued by the Company contain following descriptions on bounced landing recovery.

<1> POM (8. NON-NORMAL OPERATIONS, MANEUVERS, BOUNCED LANDING RECOVERY) (Excerpts)

• If an aircraft bounces, hold or re-establish a normal landing attitude and add thrust necessary to control the rate of descent. There is no need to add thrust in case of a shallow bounce or a skip.

• Initiate a normal go-around procedure in case of a high and/or hard bounce. Do not retract the landing gears until a positive climb rate is established in preparation for a possible second touchdown during the go-around.

<2> Training Guide (Landing Technique)

<a> In case of a light bounce:

Hold or re-establish a normal landing attitude (check PFD*4 for attitude degrees).

• Never increase a pitch attitude to avoid a possible tail-strike.

• Never increase a pitch attitude particularly after a firm touchdown followed by a high pitch rate.

Note: Spoiler extension may cause a pitch up effect.

• Continue landing keeping thrust at idle.

<b> In case of a high bounce:

Never attempt to land. Following go-around procedure can be applied.

• Never increase a pitch attitude as it could cause a tail-strike.

• Initiate a go-around by operating TOGA switch and advance thrust levers to the go-around position.

• Follow a normal go-around procedure.

• Prepare for a possible second touchdown during the go-around.

*4 PFD (Primary Flight Display) means an integrated instrument to indicate the necessary flight information like an attitude, an altitude, an airspeed and others.

	• Never attempt to avoid a second touchdown. The second touchdown does not damage the aircraft as far as the attitude is maintained. Note: PM should check a pitch angle in PFD and call out "PITCH" if the pitch angle is extraordinarily high so that a tail strike can be avoided. (6) Go-Around The go-around procedure until retracting the landing gears is described in 5. NORMAL OPERATIONS/ APPROACH AND LANDING in the POM as outlined below. • PF pushes TOGA switch on the thrust levers simultaneously with calling out " GO-AROUND" and "TOGA" and manually advances the thrust levers to their go-around position, and calls out "SET GO-AROUND THRUST" "FLAP 15". • PF rotates the nose smoothly toward 15 º nose up attitude. • PM monitors PF's operations and set the thrust and the flaps in accordance with instructions from PF. • PF and PM retract the landing gears after confirming that altimeters show positive climb rate. (7) Tail Strike <1> Factors The FCTM lists following factors of tail strike upon landing. • Unstabilized approach • Holding off in the flare • Trimming during the flare • Mishandling in the crosswind • Over-rotation during the go-around <2> Pitch Angle POM 4. LIMITATIONS and the FCTM include following descriptions on pitch angles at which the lower aft fuselage contacts the ground. • Take-off (Main Gear Struts Fully Extended) : 10 º • Landing (Main Gear Struts Fully Compressed) : 8.2 º (8) Provision on Call-Out <1> 2.2.2 General Operational Policy, OPERATIONAL POLICY in the FOM of the Company stipulates that PM must make a call-out if PM recognizes any deviation or possibility of the deviation from the SOP or the intended flight path. The provision also prescribes that PM must take appropriate corrective actions including taking over the aircraft control for the safety of the flight unless PF takes necessary actions to respond to call-outs. <2> 5. NORMAL OPERATIONS/APPROACH AND LANDING in the POM includes descriptions regarding a call-out during approach as

stated below. (Excerpts)

CALLOUTS DURING THE APPROACH

PF	*PM*
Verify the deviation, and if appropriate, correct deviation with calling "CORRECTING" or execute missed approach with calling "GO-AROUND"	*Any excessive deviations or uncorrected minor deviations from desired flight path, airspeed or descent rate occurs, PM must callout;* (Excerpt) *"FLARE" (if a flare is not initiated at the recommended flare height)* (Excerpt) *If the approach is unstabilized or for any other reason cannot safely be continued:* *Call "GO-AROUND"*

(9) Training for the Captain and the FO

According to the training records of the Captain and the FO, the most recent training regarding the Bounced Landing Recovery is as follows.

<1> Captain

The Captain received the simulator training regarding the Bounced Landing Recovery prior to promotion to a captain for the type of Boeing 737 in May, 2017.

Afterward, the Captain received the ground school training regarding the Bounced Landing Recovery in July, 2017 before taking the operation experience training, and also received the briefing by assigned instructors during the operation experience training.

<2> FO

The FO received the training regarding the Bounced Landing Recovery in the periodic training (both ground school training and simulator training) of the first half of 2018.

3 ANALYSIS

3.1 Involvement of Weather	No
3.2 Involvement of Pilots	Yes
3.3Involvement of Equipment	No

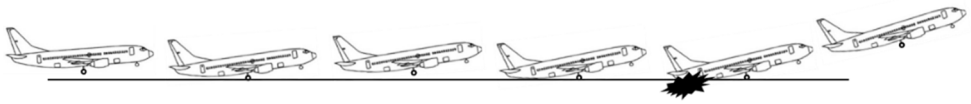
3.4 Analysis of Findings	(1) History until Bounce The Captain started a landing briefing at around 20:59. It is probable that the meteorological information which the Captain referred to at that time was the observation data issued at 20:30. It is probable that the Captain did not perform the briefing regarding a tailwind at the time of landing in view of the wind direction of 140° issued at 20:30. However, it is highly probable that the Captain assumed that the landing would be made under tailwind conditions because the aircraft was descending in the tailwind and was receiving the tailwind continuously during the final approach for the ILS approach. Meanwhile, the wind direction which the Controller provided with the aircraft was 030º. It is probable that the Captain was able to predict that wind conditions were changing as the aircraft was descending because the Captain recognized the tailwind of about 5 kt at an altitude of about 1,000 ft and almost calm wind in the vicinity of the runway threshold. However, it is probable that initiation of the flare along with reduction of the engine thrust the Captain performed, assuming that the landing would be made in tailwind conditions, followed by insufficient raise of nose up made the descent rate higher than the Captain's assumption. It is probable that the Captain was required to control the aircraft so as to cope with the changing wind conditions. It is probable, at that moment, that the aircraft touched down when its attitude was changing to nose up direction because the FO, who felt that the descent rate was high, pulled the control column. It is probable that the aircraft bounced because it touched down when its descent rate was high and its attitude was being changed to the nose up direction. (2) Tail Strike It is highly probable that the Captain executed the go-around because the Captain was unable to predict the degree of bounce. Both the POM and the FCTM prescribe that the lower aft fuselage contacts the ground at a pitch angle of 8.2 º or greater at the moment of the touchdown. The FDR records indicate that the pitch angle varied from approximately 7º to approximately 10º during the time from a second touchdown of the right main gear after initiating the go-around to the lifting off. During this period, it is highly probable that the lower aft fuselage of the Aircraft was damaged with contacting the runway because its pitch angle became too high exceeding 8.2 º. The Captain and the FO stated that the FO, who had noticed the high pitch angle after initiating the go-around, tried to restrict the movement of the control column uttering something to the Captain however, it was not possible to verify the words the FO had uttered in the CVR records. Regarding the pitch angle became too high, it is somewhat likely that because the Captain, who thought the impact after the bounce would

become hard and tried to avoid the second touchdown, performed large nose up maneuver.

The training guide of the Company prescribes that a second touchdown should not be attempted to avoid if a go-around is executed after a high bounce, aircraft is not damaged as far as it maintains its attitude even if the second touchdown has occurred, and a pitch angle is to be verified with the PFD during the recovery.

It is somewhat likely that the Captain was unable to apply the training guide information and simulator training experience to actual situation even if he had received Bounced Landing Recovery training during the simulator training to promote to a captain.

Moreover, it is somewhat likely that the fact that the go-around was initiated when the attitude of the Aircraft was changing by the nose up maneuver immediately before the touchdown and the spoilers were deploying contributed to the excessive pitch angle.



Note: Each number corresponds to the each number of the figure 2.

Figure 6 ; Image of Tail Strike

(3) Response of PM

At the time of occurrence of this accident, it is probable that the FO, who was the PM, judged the descent rate after initiating the flare was large and subsequently pulled the control column immediately before the touchdown without a call-out to avoid the hard landing.

The FOM of the Company prescribes that PM calls out the situations to PF in case that aircraft has deviated or will possibly deviate from a flight path, and in case of no response from PF, PM takes appropriate actions including taking over.

It is probable that the FO should have called out “FLARE” or “GO-AROUND” at first at the very moment the FO noticed that the descent rate after the Captain had initiated the flare was large as prescribed in the FOM and the POM considering it is somewhat likely that ambiguity over either PF or PM is operating independently could lead to a possible threat to the safety of the flight if PM intervened an operation without a call-out as in the case like this accident.

4 PROBABLE CAUSES

In this accident, it is highly probable that the lower aft fuselage of the aircraft was damaged with contacting the runway because its pitch angle became too high during the go-around following the bounce at the time of the landing.

Regarding the pitch angle became too high, it is somewhat likely that because the Captain,

who thought the impact after the bounce would become hard and tried to avoid the second touchdown, performed large nose up maneuver.

5 SAFETY ACTIONS

The Company took the following actions after this accident to prevent occurrence of similar cases.

(1) Flight Crew Involved

- Simulator training regarding "Normal Take-off and Landing" and "Bounced Landing Recovery".
- Crew Resource Management (CRM) review regarding Crew Coordination.
- Unscheduled Line Check.

(2) All Flight Crew

- Knowledge Verification regarding "Tail Strike" and "Bounced Landing Recovery".
- Issued Notice about "Basic Duty Compliance" and " Intervention for PF's control by PM".

(3) Boeing 737 Flight Crew

- Revision of Simulator Profile prior to Operating Experience (OE).
- Additional Simulator Training for the captains whose total flight time is between 100 and150 hours.
- Issued Notice about the Go-around from immediately before landing.