Civil Aviation Administration
of China

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CSC A319/B-6054 Stall During Approach

Investigation Report of Serious Flight Incident

Civil Aviation Administration of China

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Content

Investigation Report on the Stall Incident of CSC A319/B-6054 during the Approach to Destination Airport

General Introduction

On September 14th 2010, Sichuan Airlines' (referred as CSC hereinafter) A319/B-6054 was scheduled to perform flight mission 3U8949. At 09:29 (Beijing Time, the same hereinafter), during the final approach to destination airport Runway 03, significant changes occurred in the aircraft condition because of the poor weather. Low Energy, Stall and Pull Up warnings were triggered one after another, and the plane entered into stall condition. After that, the automatic protection system began to work, and saved the plan from the stall condition. The crew controlled the plane to gradually recover from the adverse condition, and landed at Ningbo airport. This event was a major aviation transportation incident.

According to *Rules of Investigating Civil Aircraft Accident and Flight Incident* (CCAR-395-R1) and Appendix 13 to *Investigation of Aircraft Accident and Incident* of International Civil Aviation Covenant, CAAC carried out investigation on this serious incident, and also invited Aviation Investigation Organization (BEA) of France (the manufacturing and designing country) and Airbus to assist the investigation. The results are stated as follows:

I Factual information

1 Incident description

On September 14th, CSC A319/B-6054 was scheduled to perform flight 3U8949. The plane took off from Chongqing airport at 07:45. At 08:47, the flight crew confirmed that the special report about the thunder storm at Destination airport (see Appendix I) sent by CSC Dispatching Office was received.

The flight crew established contact with Destination ATC tower for the first time at 09:01, reported that the estimated arrival time was 09:34, and received information of landing condition and weather condition at Destination airport "Runway 03 ILS, approach via Lishui01, ground wind 040, 03 m/s, temperature 22°C, visibility 2400m, light thunder storm, light fog, QFE 1013". Since then, the crew asked Destination ATC tower for update and confirmation of the weather condition at terminal area four times, and received responses "the terminal area is covered by thunder storm; forecast says it will turn better by 10am", "some planes ahead of you diverted to Nanjing", and "strong lightning is observed to the west of the terminal area" (see Appendix II). When the plane entered into the terminal area, the ATC tower agreed the crew to join the downwind leg to perform ILS approach.

At 09:29, strong thunder storm, together with unsteady wind in direction 340 at 7m/s, hit Destination terminal area. The plane intercepted ILS at altitude 2140 feet. Then with Auto Pilot connected, speed decreased and attitude increased gradually. When the speed reached 114kt (normal approach speed is 126kt), Low Energy Warning (SPEED) was triggered. The crew pulled out the speed knob of the Flight Control Unit (FCU), and manually selected target speed of 131kt. Auto Thrust was taking up slowly, but the speed was still decreasing with deceleration rate of 7kt per second (see Appendix III). Auto Pilot got disconnected automatically, angle of attack increased constantly and Alpha Protection function got operative. Alpha Floor was activated, speed indication showed 83kt, thrust increased to maximum automatically, the crew set the thrust lever to TOGA; Stall Warning popped up (speed indication

was 81kt, then decreased to 74kt), Flight Augmentation Computer 1 (FAC1) was inoperative[1], both pilots controlled the side stick in turn, the Flight Augmentation Computer 2 (FAC2) was inoperative. The plane started to nose down from the maximum Angle of Attack of 33.40 degrees, together with rolling to the right and losing altitude. As it took up speed gradually, the plane got recovered from stall condition. In this course, the maximum bank angle to the right reached 43.59 degrees, the maximum beta depression angle was 5.98 degrees, maximum sink rate was 3924 feet/min. Glide Slope warning, Pull Up warning, and Sink Rate warning were triggered one after another.

During descent, after the plane started to take up speed, the crew controlled the plane to gradually recover from the adverse condition and start to gain altitude, during which the lowest altitude was 884 feet. As the plane climbed to 2924 feet, the crew manually reset the 2 FACs successfully following the ECAM procedure. After this, the plane diverted to Ningbo airport, and landed safely at 10:11.

After landing, maintenance engineering checked the aircraft system to be working normally. The flight crew placed phone calls to the head of CSC Flight Operations department and Dispatch office to report on this situation. CSC decided to have this crew and plane continue to perform the flight after.

II Cause Analysis

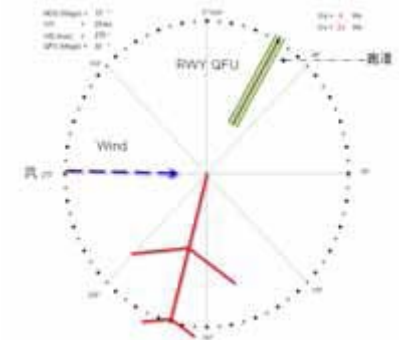
1. Analysis on Decoded QAR Data (9:29:35 – 9:30:05)

1.1 Analysis on Changes in Weather Conditions

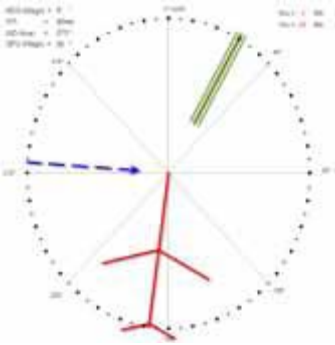
The wind direction altered from 292 to 222 degrees, wind speed altered from 25 to 50kt. Based on the changes in the altitude, speed, and attitude of the aircraft, a conclusion can be made that the plane encountered obvious turbulence at that time.

The Special Report sent by the airport and the weather condition observed by the tower controllers show that adverse weather conditions of strong precipitation, strong convection current, strong lightning, and sudden changes in wind direction and wind speed were observed at destination airport.

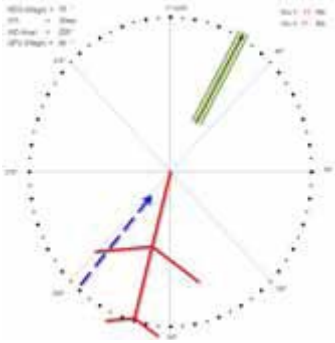
In addition, based on the decoded database of TAS, ground speed and AoA, Airbus calculated the wind speed and directions at different time before and after the incident, which are shown as follows:



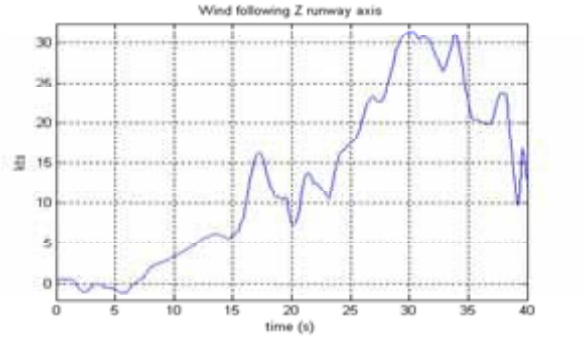
The horizontal wind speed at 09:29:20: 25kt



The horizontal wind speed at 09:29:46: 40kt



The horizontal wind speed at 09:29:51: 35kt



Vertical Downward Wind Speed Chart
From 09:29:21 to 09:29:51, the downward air flow gradually increased to 30kt (the shadow part in the chart cannot reflect the actual situation due to high AoA of aircraft.)

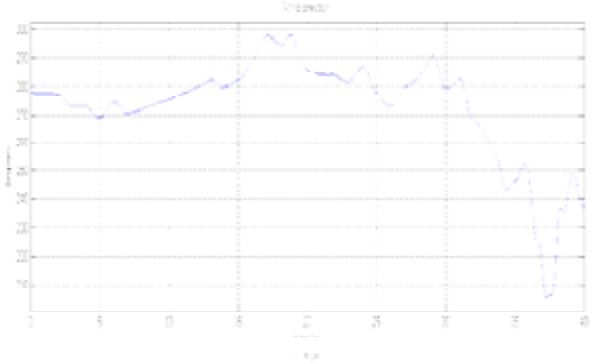


Illustration for Wind Speed and Direction During the Incident

Therefore, it can be concluded that the aircraft was confronted with both cross/ tailwind at 35kt and the vertical downward air flow at 30kt before and after the incident.

1.2 **Peak Values of Changes in Aircraft Conditions**

The biggest AoA reached +33.4 degrees and -5.98 degrees; the biggest left bank angle was 7.03 degrees, and right bank angle 43.59 degrees; the highest sink rate was 3924 feet/min; the lowest indication air speed was 74kt.

1.3 **Analysis on Changes in Aircraft Conditions**

09:29:35 Pressure altitude 1680 feet, aircraft was in Auto Pilot mode with glide slope intercepted and localizer aligned, AoA 10.2 degrees (AoA during normal approach is around 4 degrees), left bank angle 4.22 degrees, sink rate 685 feet/min, indication air speed 127kt. Under the condition of unsteady wind direction from 292 to 222 degrees, wind speed from 25 to 50kt, the AoA increased to 33.4 degrees in 16 seconds, and the bank angles swayed in a range from left 7.03 to right 43.59 degrees during a period of 20 seconds, indication air speed fluctuated and decreased to 74kt (Stall speed is around 99 kt) in 18 seconds, the lowest speed recorded.

The analysis shows that due to the adverse weather condition, the downwind and Auto Pilot system increased the AoA together constantly to make the aircraft stay on the glide slope, which led to Alpha Protection function and Low Energy warning triggered, Alpha Floor Protection activated, Auto Pilot disconnected, Stall warning triggered, FD disconnected, and abnormal PFD display when the speed decreased to 93 kt. The Alpha Protection function controlled the elevators to deflect downward to the most and maintained for 7 seconds (during which 2 FACs got inoperative one after another), the Alpha Floor protection increased the engine power into the maximum. The aircraft pitch attitude and AoA decreased, the AoA decreased from 32 degrees upward at most to 6 degrees downward; the aircraft swayed from left bank angle 2.11 degrees to right bank angle 43.59 degrees, sink rate reached up to 3924 feet/min, speed increased, and eventually the aircraft was recovered from stall. At 30:05, the crew managed to recover the plane from complex conditions at pressure altitude 884 feet (minimum altitude) and resumed to climb.

The main causes of the right bank angle up to 43.59 degrees and sink rate up to 3924 feet/min are: when the aircraft stalled, roll with one wing down was induced by the lateral force. In addition, other factors such as turbulence caused by adverse weather conditions may also cause the plane to roll to the right; while Alpha Protection function activated, together with the tendency of the plane to dive because of the stall and roll, made the plane aggravate to dive, which was the main cause of the high sink rate of the aircraft and decrease of AoA.

2. **Weather Analysis for Destination Airport**

Meteorologist drew up the following conclusions after analyzing the weather in destination Airport:

08:21 hearing thunder
08:30 heavy thunderstorm

09:00 thunderstorm weakening; as indicated by weather radar echo, thunder-clouds formed in west of the airport around 08:39, then grew stronger and moved toward airport;
09:20 Airport was covered by cumulonimbus.

To sum up, ground wind direction and wind speed continued to change from 08:48 to 10:00 and weakening thunderstorm at 09:00 grew into medium thunderstorm at 9:30, which could be explained by the microburst occurred under cumulonimbus.

Based on the preliminary investigation conducted by Southwest CAAC, the investigation team concluded that the aircraft may encounter microburst and consequential wind shear during final approach.

3. Flight Maneuver Analysis

According to decoded data of QAR and the flight crew interview record, the following analyses were made:

When aircraft attitude (including pitch attitude, roll, EPR and speed) became very abnormal during final approach, the flight crew did not stop approach or switching to manual maneuver in a timely manner.

When the Low Energy Warning occurred for the first time (09:29:38), the pilot did not follow the manual procedure to push the thrust lever, but tried to increase aircraft speed by adjusting target speed in FCU (for 8s), missing the best chance to avoid the complex situation.

Aircraft stall warning was triggered at IAS 81kt. As indicated by QAR data, flight crew didn't apply latest Stall Recovery Procedure issued by Airbus.

After aircraft stalled, two pilots reacted out of instinct with side stick input and pedal input. According to QAR data, when angle of attack protection was triggered, aircraft tried to pitch down. To certain extent, the deflection of elevator for nose-down offset pilots' side stick input. Roll and pedal control worked normally.

4. Analysis of aircraft auto protection

When the aircraft continued to pitch up and angle of attack was increasing as well to a point, exceeding the maximum alpha setting, AP was disconnected and Alpha Floor was triggered. Under alpha floor protection, the warning occurred were consistent with aircraft attitude. Generally, aircraft auto protection functioned normally in line with aircraft design.

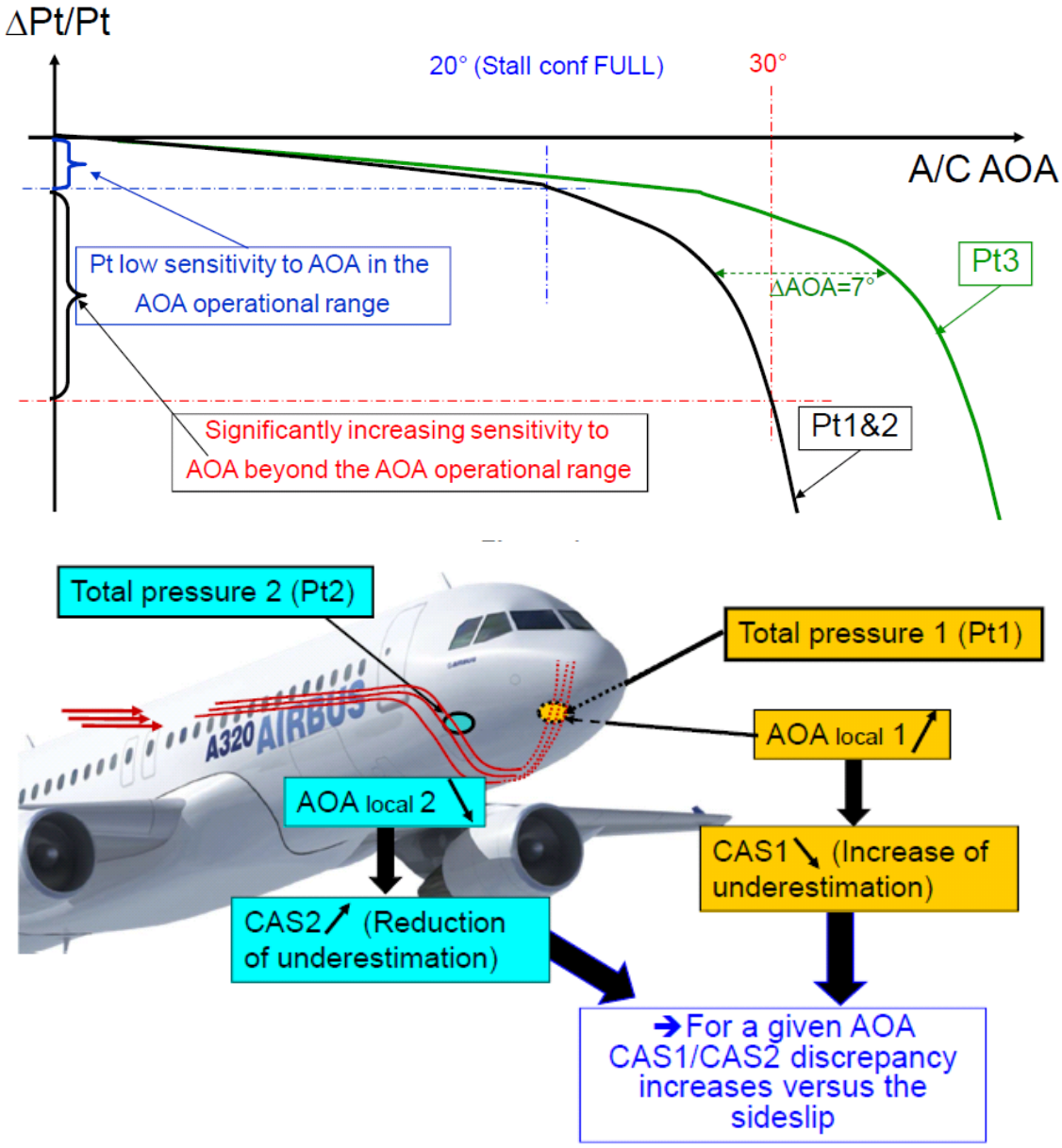
After alpha floor protection was triggered, two FACs got inoperative consecutively. According to QAR analysis, aircraft recovered from stall even with the two FAC failures.

5. Analysis of aircraft recovery

In order to fly along the glide slope, the aircraft under control of Auto Flight Control System continuously increased attitude. Due to the severe weather conditions, low energy warning and alpha floor were triggered, AP disconnected, stall warning

occurred, FD disappeared and PFD worked abnormally. Under alpha floor protection, elevator deflected to the maximum range for 7s (In between, two FACs got inoperative consecutively). Later, pitch attitude and AoA decreased with right bank angle (maximum 43.59 degrees) and increasing sink rate to 3924ft/m. Finally aircraft gained speeds and recovered from stall. During descent, flight crews maneuvered the aircraft out of complex status, recovering to positive climb rate.

6. **Analysis of windshear function**
   Windshear alert applies to altitude from 50ft to 2300ft. Caution and Warning may appear below 1200 feet.
   According to QAR, windshear happened above 1200ft, so windshear warning was not triggered at this time.
7. **Cause analysis on the inoperation of two on-board Flight Augmentation Computers (FAC) when the plane was in complex conditions**
   According to the working principle of FAC provided by Airbus, when any of the following speed limits cannot be computerized, such as minimum VLS, V stall warning, Vctrend, VMAX [Maximum VFE, or Maximum VMO/MMO], VFLAP, VSLAT, VFEN, next VFNE etc., the computer will cause the failure of FAC. Besides, when FAC calculates speed limit, at least one SFCC, one ADR and one IRS should work normally at the same time.
   Based on the analysis on troubleshooting data recorded by FMGC after the incident, it's found out that at 09:29:56, the plane lost Cat. 3 Automatic Landing System dual-channel function; auto thrust was in connecting condition, two sets of FD and AP were disconnected, and at least one set of ADR data was not adopted by any FAC; Besides, Elevator Aileron Control Computer also recorded the disconnection of Auto Pilot.
   FAC troubleshooting data record information shows that at 09:29:56, FAC ignored the data of 3 ADRs because parameter results compared were beyond the limit (parameters between AoA sensors or between Calibrated Air Speeds); the decoding record also shows that at 09:29:58, two FACs returned to normality after resetting. Since FAC only monitors the CAS and AoA, the data in AoA sensor 1 and 2 till the incident occurred had been the same. From this we can derive that the reason why FAC failed to apply ADR is that the difference between CAS 1, 2 and 3 was over 10kt.
   The full pressure using No.3 ADR to measure CAS was from No.3 full pressure sensor, whose accuracy was, unlike No.2 and 3, within the effective working range of AoA sensor. This might explain the reason why, at the time of the incident, the difference between CAS 3 and CAS 1 and 2 was over 10kt.
   CAS is derived from full pressure and static pressure. If the AoA exceeds its sensor's effective working range, the full pressure accuracy will decrease as the AoA increases, making CAS significantly below its actual level as the AoA increases, which causes huge deviation. At the same time, sideslip can also significantly impact the CAS. (Refer to the following chart)



Besides, for the given AOA, the deviation between CAS No.1 and 2 is related to sideslip. At the time of the incident (09:29:56), sideslip also occurred. This further explains why the deviation between CAS No.1 and No.2 was over 10kt, which caused FAC's failure to apply all the three ADR data.

In addition, DAR decoding revealed that from 29:51 to 29:56, the difference between sampled right and left IASs was over 10kt for 5 seconds. Therefore, the most possible reason for FAC not using ADR information could be that the speed difference between three Calibrated Air Speed (CAS) systems was over 10kt.

If the speed limit computerization failed for 1.1 seconds, two sets of Auto Pilot and Flight Director will automatically disconnect and disappear. This corresponds to the fact that two flight directors disappeared at 09:29:54.

According to the design requirement, if FAC doesn't use any of three ADRs' data, it will restrict the yaw damper within the scope of +/- 5 degrees. This corresponds to the fact that, as the decoding record shows, yaw damper was limited within the scope of +/- 5 degrees from 09:29:53 to 09:29:58.

When speed limit computerization is no longer valid, the speed strip on Primary Flight Display (PFD) will display: real time CAS; selected or managed CAS (if selected); speed limit warning flag "SPD LIM" will appear at the bottom of speed strip.

"FAC speed limit inoperative" during flight is reversible. As long as speed limit computerization recovers, it will work normally.

From this, we can derive that: when the plane was in complex conditions, airflow was critically unsteady; with the increase of AoA, the pressure accuracy measured by full pressure system decreased accordingly, which caused the deviation of different CAS systems. When AoA continued to increase beyond its effective working scope, airspeed deviation between different CAS systems were over 10kt. This ultimately led to FAC's failure to use ADR data and its inoperative status. So it was not caused by true fault, namely the "malfunction" condition of FAC defined by Airbus. The crew successfully reset the two FACs after the incident, proving the above analysis was right.

8. Analysis on condition of entering "abnormal attitude laws"

According to the information (FCOM 1.27.30 Page 7) provided by Airbus, the system applies abnormal altitude laws if the aircraft exceeds any of the following limits and at least two information sources of their data sources exceed their limits for more than 1 second:

Pitching attitude: > 50 degrees nose up or 30 degrees;

Bank Angle: > 125 degrees;

AoA: > 30 degrees, down: A320 > 10 degrees; A318, A319 and A321 > 15 degrees;

Speed: > 440kt; or < 70kt to 90kt (subject to plane's pitching attitude);

Mach number: > 0.91

In this incident, AoA sensor 1 was lower than 30 degrees all the time, and AoA sensor 3 was not recorded in DFDR, but which can be confirmed as lower than 30 degrees.

Although the plane went through big attitude change during the incident, these changes do not match the requirements of entering abnormal attitude laws. Therefore, the plane was still under the normal laws in the incident.

9. After Alpha Floor protection was activated, AoA kept increasing and aircraft stalled

Alpha Floor protection is only the function of thrust. Activating this function will increase the thrust to TOGA, instead of directly controlling plane's pitching attitude. At stalling, the first maneuver is to decrease AoA. After stall recovery, increase the speed according to needs.

In accordance with the flight manual of Airbus aircraft (A319/320/321), the Alpha Protection function is described as follows: under normal laws, when the plane is in full configuration, if AoA is bigger than alpha prot, the system will change the elevator from normal mode into protection mode, and give the maximum nose down input. Within the scope of alpha protection, namely between alpha prot to

alpha MAX (refer to the following chart), AoA will be directly controlled by side stick. Even if the pilot pulls the side stick to the very back, AoA will not exceed the alpha MAX. This function to protect from stall and windshear enjoys higher priority over other protections.
When AoA is bigger than alpha prot plus 1 (alpha prot + 1 =13 degrees), Auto Pilot will disconnect. This applies with design requirement.

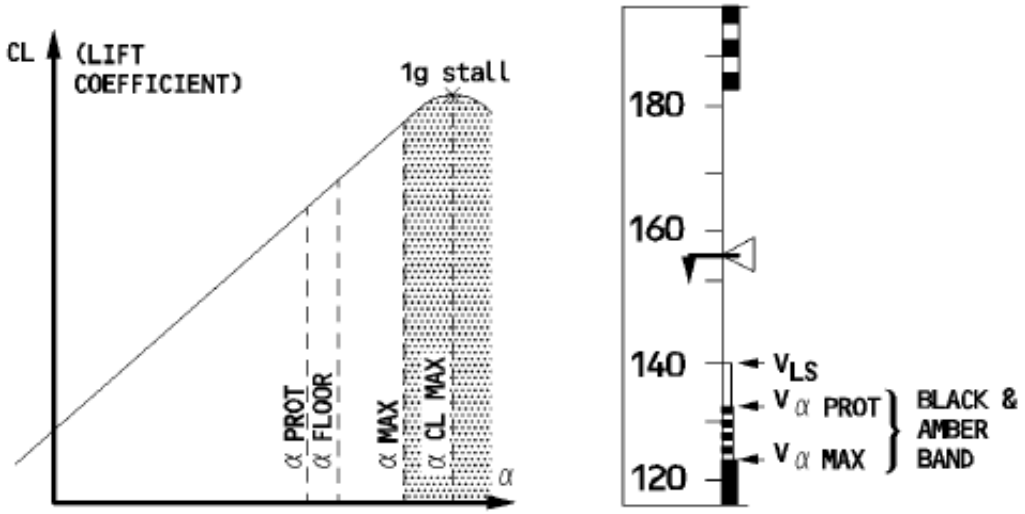


Illustration for the relationship between protected AoAs

According to the conversion between AoA sensored angle and actual aircraft AoA provided by BEA /Airbus: actual AoA = sensored AoA/ K+I (among which, the two coefficients K and I are variables related to aircraft, flaps and slats configuration and AoA. If in full configuration, when the sensored AoA is less than 29 degrees, K=2.089, I=-2.487; when the sensored AoA is bigger than 29 degrees, K=1.700, I=5.667), convert the AoA recorded in the decoding and send it to the relevant equipment or system after comparison.

The decoding of this incident showed that at 09:29:50, Alpha Protection was triggered, and ordered maximum elevator nose down input, elevator deflected downwards to the maximum of 16 degrees for 7 seconds, during which plane's pitch attitude declined from up 34 to 4 degrees, and AoA rapidly climbed to 32 degrees and then gradually decreased to 19.33 degrees. From this we can see that AoA increased rapidly, exceeded stall warning threshold (23 degrees under normal laws) to a maximum of 32 degrees with a right bank angle of 44 degrees; Alpha Protection was triggered and gave the maximum nose down input to elevator; AoA gradually decreased to lower than alpha prot.

At 09:29:51, AoA exceeded 13 degrees (in full configuration), and Alpha Protection function was triggered. The engine EPR was 1.27 at that time, and increased to TOGA in less than 2 seconds; AoA went beyond alpha prot + 1 (=13 degrees), and Auto Pilot was disconnected.

At 09:29:52, stall warning appeared and lasted for 6 seconds.

From this we can see that: after AoA exceeded the stall limit, the plane stalled. Meanwhile, Alpha Protection function was activated to make the aircraft nose down, and gradually recovered the aircraft, which demonstrated the effective protection.

10. About the timing of stall warning

The stall warning is triggered on the basis of aircraft AoA, not speed. For the given AoA, its stall AoA is 23 degrees. FDR only records samples of calibrated air speed and stall data every one second. When AoA is increasing beyond its limit, the accuracy of full pressure data will be reduced, as a result accuracy of CAS is reduced at large AoA. When calculating the stall speed, the load factor at that time shall also be considered. As for this incident, the vertical load factor was 0.8 when the aircraft stall warning was triggered. When the weight of the full configured A319 is 56.4 tons, its stall speed is 99kt; given its vertical load factor of 0.8 during stall, the actual stall speed at that time should be 99*0.8=79.2kt. However, Airbus found out from the decoded data that CAS was 93kt to 81kt when the actual stall warning was triggered. This was caused by the discontinuity of data sampling between CAS and stall speed with 1 second gap. So it can be indicated only by a speed range.

Considering the above analysis, it can be concluded that the stall speed at that time was around 79kt since the stall warning was based on the aircraft AoA. The triggered stall warning as shown by the decoded data was between 93kt and 81kt (CAS), higher than 79kt, demonstrating that the stall warning was triggered before the aircraft stalled.

11. Analysis of the flight crew's compliance with FCOM

According to Airbus Flight Crew Operational Manual (FCOM 3.04.91), the supplementary techniques[3] under the conditions of windshear and downburst are as follows:

During approach:

Delay landing or divert to another airport until the conditions are more favorable

Evaluate conditions for a safe landing by using observation and experience and checking weather conditions;

Use weather radar for observation;

Select the best runway for landing with the most appropriate approach NavAid;

Select Flap 3;

Use managed speed in approach phase;

Check both FDs engaged in ILS, FPA or V/S

During this flight, the crew didn't act properly in making decision about weather, operating equipment and handling flaps under the weather condition of the day.

[3.] Airbus also provides documents related to windshear identification, for instance: FCOM Notification 803/1 "Operation in windshear/downburst conditions"; Flight operating Briefing Notes "Adverse weather operations/windshear awareness", and etc.

12. Analysis of aircraft stalling

Under the Influence of microburst and the following windshear, the aircraft attitude changed significantly. Although the Alpha Protection function was activated before stall, it was still quite hard to effectively stop the aircraft from

stalling, because the energy produced by the weather at that time had exceeded that of auto protection system.

III. Conclusion

1. Findings

1.1 The crew did not pay enough attention to the complex weather condition, and their decision-making ability was weak.
The crew had made wrong decisions in the severe weather condition. Although ATC informed the pilots of the weather conditions and other planes' diversion, the flight crew continued to launch the approach.

1.2 The alternative plan prepared for complex weather condition was insufficient. When wind shear became obvious, pilots took no resolute action to stop the approach.

1.3 The crew failed to respond as per manual.
When the aircraft attitude was gradually deviating from norm, air speed decreased and low energy warning appeared, the pilots intervened in the AP control by choosing the speed manually instead of pushing the throttle forward as QRH2.03, leading to complex situation, including increasing attitude, low airspeed, Alpha Protection triggered and stall.

1.4 The Crew Resource Management was a chaos. When aircraft was in complex conditions, pilots reacted out of their instinct, leading to dual side stick inputs for as long as 12s.

2. Cause

In accordance with article 3.13 of Civil Aircraft Incident, this is a serious air transport incident, caused by flight crews' inappropriate decisions and handling under adverse weather conditions.

IV. Safety Recommendations

1.1 CSC shall strengthen their trainings about safety awareness and skills, preventing flight crews from reckless flight in severe weather conditions.

1.2 When manufacturers update or revise critical manuals about flight maneuver procedure, airlines shall organize relevant trainings on time and on quality.

1.3 Under complex weather conditions, flight crew shall keep alert to all relevant flight data, improve their situation awareness and take early preparation and decisive action, instead of making reckless decision and actions.

1.4 Airlines shall improve their trainings on safety information reporting; strengthen staff's awareness about reporting safety information and protecting evidence. In particular, the report about serious safety events shall be as complete and detailed as required by regulations and evidence shall be protected.