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IN THIS ISSUE

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Editorial

Tail strike though infrequent, when occurs is a matter of serious concern as it could result in a significant structural damage. There is an associated high repair cost and loss of revenue. There is also a possibility of subsequent failure of rear pressure bulkhead due to improper/poor repair leading to a catastrophic accident like the in-flight breakup of china Airlines B747.

Tail strike is the subject of this issue. First we look at Kuwait Airways A300 tail strike accident at Jeddah followed by few other cases.

Tail strike can be prevented by a well trained and knowledgeable flight crew following prescribed procedures. So we discuss tail strike prevention in detail.

Your feedback is valuable. Suggestions and contributions can be sent to our office. Happy reading and many more safe landings.

Kuwait Airways flight KU785 tail strike during landing at Jeddah

Based on DGCA aircraft accident report

On 29th September 2004, at about 10:48:00 hours GMT, Kuwait Airways flight Ku785, an Airbus A300-605(9K-AMB) took off from Kuwait International airport on a scheduled flight to Jeddah with 213 passengers.

The takeoff and cruise to Jeddah were uneventful. The flight started descend and approach to Jeddah under radar vectoring for ILS R/W 34C. First officer was the pilot flying (PF) and the captain was the pilot monitoring (PM). With auto-pilot and auto-throttle engaged the approach was uneventful. At 700 ft RA, both autopilots were disengaged and auto-throttle remained engaged. Weather was normal with wind below 15Kt at 290 deg.

At 50ft RA the crew experienced sudden sink and the aircraft landed with higher than normal rate of descend and bounced to a height of over 5 ft. The crew attempted to control the second landing by increasing the pitch attitude. The aircraft made a hard touch-down with high pitch attitude resulting in tail strike. Landing continued down to taxi speed and the aircraft taxied to the parking stand.

The crew did not report any abnormal condition during the final approach nor declared any emergency after landing. After parking and completion of the checklists, a nil defect entry was made in the technical log and the refueling for the return trip was ordered.

There were no injuries to either the crew or the passengers.

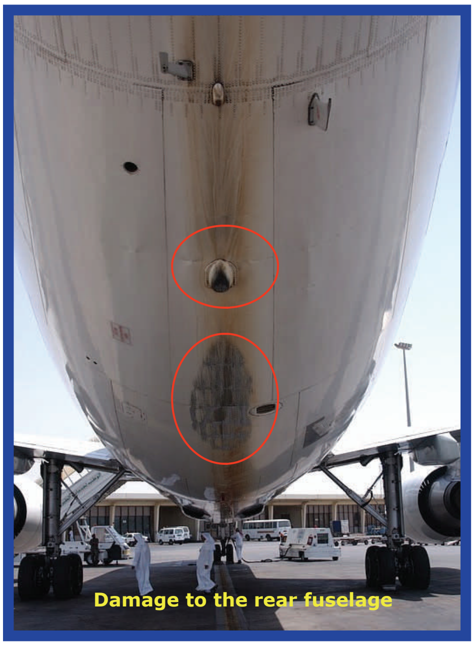
The station ground engineer observed the intensive damage to the lower part of the tail section of the fuselage(see pictures in page 2) and reported to the crew. The damage to the aircraft included— Severe damage to the aft fuselage structural frame #77; sheared rivets on frame #77; Badly scratched and cracked outer skin; tail skid abrasion shoe worn beyond orange marking; failure of 3 support rods between frame #77 and cross beam.

The aircraft was declared AOG at Jeddah.

Initial investigation was carried out by the Director of Safety, Saudi Arabia Presidency of Civil Aviation (PCA), along with KAC crew. Later Kuwait DGCA investigated the accident

The aircraft departed Kuwait with weight and CG within limits for takeoff and landing at destination.

During landing, crew experienced high rate


Damage to the rear fuselage

of descent below 50 ft. DFDR data showed several elevator inputs between 65 ft and ground.

- At 50ft, PF applied 2° nose up elevator
- At 25ft, PF applied 5° nose up elevator
- At 15ft, PF reduced to 2° nose up
- At 5ft, PF increased to 10° nose up

elevator.

The aircraft landed with a descent rate of 450 ft/min and a pitch attitude of 9.5° nose up resulting in a bounce. After the bounce, the PF did not apply the correct recovery technique given in FCOM. Instead he continued with the pitch up command resulting in aircraft pitch of +12.4° leading to tail strike. (with main landing gear fully compressed, tail strike occurs at a pitch of +11.4°)

The investigation found that

- Neither the weather, wake turbulence of the preceding aircraft nor the ATC and ground aids were the contributing factors for the accident
- The tail strike was due to the landing technique of PF, passiveness of the PM and flight deck crew's lack of knowledge and unfamiliarity with bounce recovery technique.
- The presence of a third pilot (Dead Head Captain) in the cockpit and his continued chat with the Captain was a contributing factor.

DGCA made the following recommendations

- KAC to amend the pilot training program to cover bounce landing avoidance and recovery for all type rating and recurrent training
- To emphasize that landing techniques and procedure to avoid risk of tail strike occurrence to be according to the aircraft FCOM.

Notwithstanding the losses due to the nonavailability of the aircraft for opeations, the repair costs arising out of this tail strike was around US $ 2.6 million.

Some Tail Strike Examples

While the above tail strike accident occurred during landing, tail strike can occur during takeoff as well. Following are some tail strike examples.

- On October 14, 2004, an MK Airlines B747 made a reduced power takeoff from Halifax on a cargo flight to Spain which resulted in tail strike. The aircraft overshot the end of the runway, got airborne. After striking an earthen bern, the aircraft tail section broke away and the aircraft struck terrain and was destroyed killing seven members onboard. (See June 2007 issue of Flight Safety for details of this accident)
- On March 12, 2003, a Singapore Airlines Boeing 747-412 suffered a tail strike on take-off in Auckland, New Zealand, and became airborne just above the stall speed. The aft pressure bulkhead was severely damaged, but the crew managed to land safely. The cause of the tail strike was a result of the flight crew entering a take-off weight 100 tonnes less than the actual weight into the Flight Management System (FMS), resulting in low take-off speeds being generated. There was no crew cross-checking of the speeds.
- On March 11, 2003, a Boeing 747-300 in Johannesburg, South Africa, had a tail strike on take-off. The flight engineer had entered the zero fuel weight of 203,580 kg instead of the takeoff weight of 324,456 kg into the hand-held performance computer, and then transferred the incorrect computed take-off speeds onto the take-off cards.
- On June 14, 2002, an Airbus A330 had a tail strike on take-off in Frankfurt, Germany, because incorrect take-off data was entered into the FMS. The tail strike was undetected by the flight crew, but they were notified by air traffic services during the climb-out. The aircraft sustained substantial structural damage to the underside of the tail.
- On December 28, 2001, a B747-200 cargo aircraft had a tail strike on take-off in Anchorage, Alaska, and sustained substantial damage. The crew did not account for the weight of the additional fuel (about 45,360 kg) taken on board in Anchorage, and inadvertently used the same performance cards that were used for the previous landing. The crew members were unaware that the tail had struck the runway until after arrival at their destination.

A study by Douglas Products Division on tail strikes came with the following two conclusions:

- The frequency of tail strike is higher for some models on takeoff, and for other models on landing. The overall incident rate varies from one model to another as well as over time. For example, one model experienced a high incident rate upon entry into service, followed by a reduced rate and then an increased rate about six years after initial entry into service.
- Though tail strike occurs in both daylight and darkness, and in both good and bad weather, the amount of flight crew experience with the model of aircraft flown is a more significant factor. While tail strike may occur to pilots with abundant flight time in a model, most occur to pilots who are transitioning from one aircraft model to another and have fewer than 100 hours of flight time in the new model. Incidents are greatest among pilots during their first heavy-weight operations in the new model, especially when the weather is marginal.

TAIL STRIKE PREVENTION

Based on Airbus and Boeing notes on tail strike prevention

Tail strikes occur when the tail of an aircraft touches the runway during takeoff or landing. It can occur on any type of aircraft but long aircraft may be more prone to it as the tail strike occurrence is directly related to pitch attitude, aircraft geometry and the main landing gear status.

Tail strikes can cause significant damage to the aircraft resulting in heavy repair costs and lost revenue. In some cases, the damage to the rear pressure bulkhead, if not repaired properly could result in catastrophic failure much later during the service life of the aircraft as it happened in the case of China airlines B747.

Flight crew members may not always be aware that a tail strike has occurred at takeoff, because the impact may not be felt. Analysis of in-service events indicates that, in some cases, the tail scraped the runway, so gently, that it was not detected by the flight crew. In such cases, the flight crew may be alerted of a suspected tail strike by passengers, cabin crew members, crew from other aircraft near the runway, ATC or ground personnel.

As a result, the flight crew will then be aware that the fuselage skin is probably damaged, and that the cabin must, therefore, not be pressurized. Cabin vertical speed therefore may become the same as aircraft vertical speed, which should then be limited for passenger comfort.

Flight at an altitude that requires a pressurized cabin must be avoided, and a diversion to a suitable airport must be performed so that damage assessment can take place.

Statistics reveal that about 25% of reported tail strikes occur during take-off and 65% during landing.

Regardless of the aircraft model, tail strikes can have a number of causes, including gusty winds and strong cross-winds. But environmental factors such as these can often be overcome by a well-trained and knowledgeable flight deck crew following prescribed procedures.

Aircraft manufacturers conduct extensive research into the causes and look for design solutions to prevent them. In the inevitable event of tail strike, to minimize the damage to the aircraft tail structure, tailskid abrasion shoes are incorporated. There are design solutions like the improved elevator feel system and the tail strike protection system on some models.

As part of the certification process exhaustive flight tests are conducted for tail strikes. During these flight tests, take off test conditions are specifically designed to investigate the impact of early rotation, rapid rotation, no flare during landing, and long flare. From these tests, an acceptable margin per certification criteria is established for the design operational use of the aircraft.

The aircrafts meet or exceed the design certification criteria for takeoffs and landings, as well as for crosswind takeoffs and landings. Criteria for engine-out takeoffs and landings are also evaluated.

Analysis of in-service tail strike incidents revealed eight risk factors one or more of which precede a tail strike: mistrimmed stabilizer; rotation at improper speed; excessive rotation rate; improper use of the flight director; unstabilized approach; holding off in the flare; mishandling of crosswinds; and over-rotation during go-around. There are other factors but these eight play a significant role in tail strike. Most importantly, each of these is under the direct control of the flight crew, and therefore can be avoided with proper understanding and training.

These risk factors can be grouped into two categories i.e. Takeoff risk factors and Landing risk factors.

TAKEOFF RISK FACTORS:

Any one of the following four takeoff risk factors may precede a tail strike:

- Mistrimmed stabilizer
- Rotation at improper speed
- Excessive rotation rate
- Improper use of the flight director

Mistrimmed stabilizer

The main purpose of the pitch trim setting for takeoff is to provide consistent rotation characteristics. If, for any reason, the trim setting does not match the CG position, the aircraft will not rotate as usual (see Figure 1):

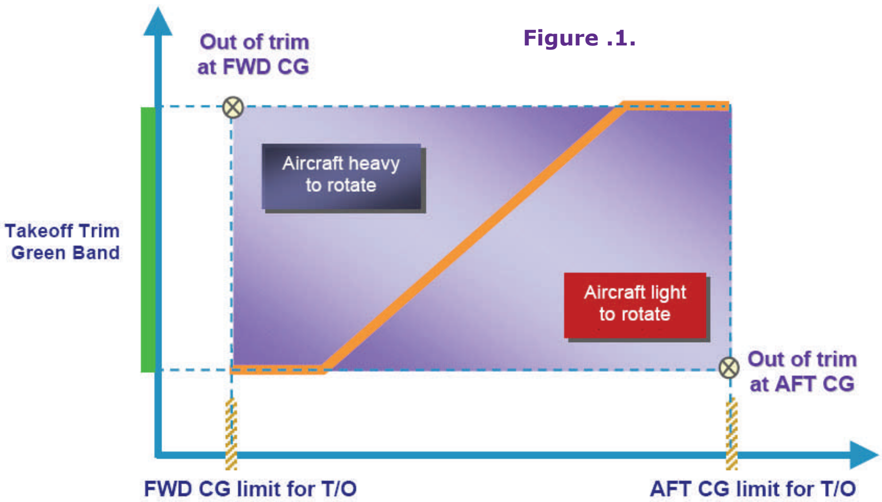
With a forward CG or the pitch trim erroneously set to the nose-down direction, the flight crew will notice that the aircraft is "heavy to rotate", and that aircraft rotation will be very slow in response to the usual takeoff control input

With an aft CG or the pitch trim erroneously set to the nose-up direction, the flight crew might have to counteract an early autorotation, until V_R is reached.

A mistrimmed stabilizer during take-off is not common and is a result of using erroneous data, the wrong weights, or an incorrect CG. While the information presented to the flight crew is accurate, but it is entered incorrectly either FMS or to the stabilizer itself.

The flight crew can become aware of the error and correct the condition by

Figure .1.



challenging the reasonableness of the load sheet numbers. A flight crew that has made a few takeoffs in a given weight range knows roughly where the CG usually resides and approximately where the trim should be set. Boeing suggests testing the load sheet numbers against past experience to be sure that the numbers are reasonable.

While a nosedown mistrim cannot cause a tail strike, noseup mistrim can place the tail at risk. This is because the yoke requires less pull force to initiate rotation during takeoff, and the PF may be surprised at how rapidly the nose comes up. With the Boeing-recommended rotation rate between 2-3degrees/second, depending on the model, and a normal liftoff attitude, liftoff usually occurs about four seconds after the nose starts to rise. However, with the stabilizer noseup mistrim , the aircraft can rotate 5 degrees/second or more. *With the nose rising very rapidly, the aircraft does not have enough time to change its flight path before exceeding the critical attitude. Tail strike can then occur within two or three seconds of the time rotation is initiated.*

If the stabilizer is substantially mistrimmed noseup, the aircraft may even try to fly from the runway without control input from the PF. Before reaching V_R and possibly as early as approaching V_1 the nose begins to ride light on the runway. Two or three light bounces may occur before the nose suddenly goes into the air. A faster-than-normal rotation usually follows and, when the aircraft passes through the normal liftoff attitude, it lacks sufficient speed to fly and so stays on the runway. Unless the PF actively intercedes, the nose keeps coming up until the tail strike occurs, either immediately before or after liftoff.

Rotation at Improper speed

An incorrect V_R may cause an early rotation, that will lead to an increase in pitch attitude at liftoff and, as a result, a reduced tail clearance.

Analysis of in-service events shows that early rotations can occur when:

- The calculated V_R is not correct for the actual aircraft weight or flaps configuration (for example, computing V_R using the ZFW instead of the actual takeoff Gross Weight)
- There is a mistake in the displayed V_R due to an FMS CDU typing error.
- The pilot flying commands rotation below V_R due to gusts, Windshear, obstacle on the runway, or confusion in callouts.

An example of an unusual situation discovered during the examination of in-service events was a twinjet going out at close to the maximum allowable weight. In order to make second segment climb, the crew had selected a lower-than-usual flap setting. The lower flap setting generates V speeds somewhat higher than normal and reduces tail clearance during rotation. In addition, the example situation was a runway length-limited takeoff. The PF began to lighten the nose as the aircraft approached V_1, which is an understandable impulse when ground speed is high and the end of the runway is near. The nose came off the runway at V_1 and, with a rather aggressive rotation, the tail brushed the runway just after the aircraft became airborne.

An error in V_R speed resulted in a tri-jet tail strike. The load sheet numbers were accurate, but somehow the takeoff weight was entered into the FMS 100,000 lb lower than it should have been. The resulting V_R was 12 knots indicated air speed (KIAS) slow. When the aircraft passed through a nominal 8-deg liftoff attitude, a lack of sufficient speed prevented takeoff. Rotation was allowed to continue, with takeoff and tail strike occurring at about 11 deg. Verification that the load sheet numbers were correctly entered may have prevented this incident.

Both flight crew members should crosscheck the V_R to verify that the inserted value is the appropriate value for the aircraft weight and configuration. A review of takeoff data is part of the takeoff briefing, and of the briefing confirmation during taxi.

Excessive rotation rate

Rotation rates that are too fast increase the risk of tail strike, whereas rotation rates that are too slow increase the takeoff distance and takeoff run.

If the established rotation rate is not satisfactory, the pilot must avoid rapid and large corrections, which cause sharp reaction in pitch from the aircraft.

If, to increase the rotation rate, a further and late aft sidestick (or control column, as applicable) input is made around the time of liftoff, the possibility of a tail strike is significantly increased. This is especially a risk on aircraft that may have a large inertia (e.g. long aircraft) since the initial rotation rate produced by a given sidestick (or control column, as applicable) input takes time to build up (when the rotation rate has developed, it remains relatively constant for a stick position).

For long aircraft, the sensory feedback provided to the flight crew, during rotation, is different to that provided for shorter aircraft due to the length of the fuselage and its flexibility:

- The aircraft is longer, therefore for a same rotation rate, the local vertical acceleration sensed by the flight crew is higher.
- Due to the flexibility of the aircraft, firstly, the pilot senses a delay in the rotation; then, the sensory effects of the local vertical acceleration are somehow amplified.

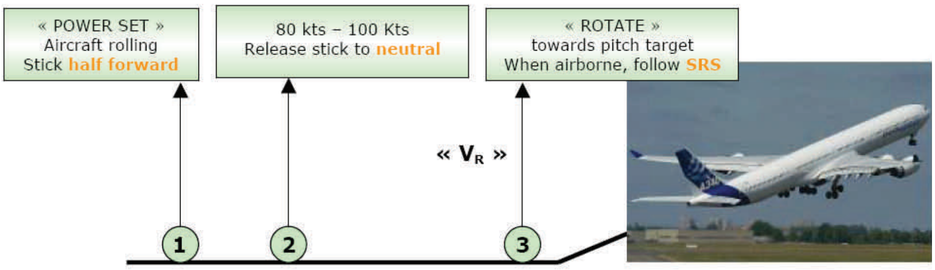
This sensory feedback shall not lead the pilot to overact by making large changes in the sidestick (or control column, as applicable) inputs, which lead to potential large pitch oscillations.

At V_R, the flight crew should initiate the rotation with a smooth positive backward sidestick (or control column) input in order to achieve a continuous rotation rate of approximately 3°/sec. Avoid aggressive and sharp inputs.

The higher the inertia of the aircraft is (e.g. long aircraft), the more it is important to initiate the rotation with a smooth positive nose up order.

The takeoff sequence figure in the next page indicates the sequence for a standard takeoff. However, flight crewmembers should keep in mind that this sequence can vary depending on the scenario (e.g. Windshear), and the PF should be ready to react in any abnormal situation.

Flight crews operating an aircraft model that is new to them, especially when transitioning from unpowered flight controls to ones with hydraulic assistance, are most vulnerable to using excessive rotation rate. The amount of control input required to achieve the proper rotation rate varies from one model to another. When transitioning to



Typical takeoff sequence

a new model, flight crews may not consciously realize that it will not respond to pitch input in exactly the same way.

As simulators reproduce aircraft responses with remarkable fidelity, simulator training can help flight crews learn the appropriate response. A concentrated period of takeoff practice allows students to develop a sure sense of how the new aircraft feels and responds to pitch inputs. On some models, this is particularly important when the CG is loaded toward its aft limits, because an aircraft in this condition is more sensitive in pitch, especially during takeoff. A normal amount of noseup elevator in an aft CG condition is likely to cause the nose to lift off the runway more rapidly and put the tail at risk.

Improper use of Flight Director

Flight director is designed to provide accurate pitch guidance only after the aircraft is airborne, nominally passing through 35 ft (10.7 m). With the proper rotation rate, the aircraft reaches 35 ft with the desired pitch attitude of about 15 deg and a speed of V2 + 10 (V2+ 15 on some models). However, an aggressive rotation into the pitch bar at takeoff is not appropriate and may rotate the tail onto the ground.

The PF must perform the rotation mainly head-up, using visual references outside the aircraft until airborne, or at least until the visual references are lost, depending on visibility conditions. The PF must then monitor the pitch attitude on the PFD.

Other factors:

In addition to the above four major factors, the following three factors also affect the takeoff tail strike risk and should be considered.

THRUST/WEIGHT RATIO

The possibility of a tail strike increases during takeoff with low thrust to weight ratios, where the aircraft performance is limited by the second-segment climb gradient.

Heavy aircraft taking off from high altitude airport or in hot conditions are more sensitive to tail strikes than other aircraft.

SLATS/FLAP CONFIGURATION

For a given aircraft weight, a variety of flap configurations are possible. In general, a high flaps configuration decreases the probability of a tail strike, by reducing the required pitch for liftoff.

When performance limits the takeoff weight, the flight crew uses the maximum thrust available and select the configuration that provides the highest takeoff weight.

When the actual takeoff weight is lower than the maximum permitted weight, the flight crew uses a flexible takeoff thrust. For a given aircraft weight, several flap configurations are possible. Usually, the flight crew selects the configuration that provides the maximum flexible temperature, in order to increase the engine lifespan.

The configuration that provides the maximum flexible temperature varies with the runway length. Usually, the highest flexible temperature is obtained with the highest flaps configuration on short runways, but with the lowest flaps configuration if the runway is medium or long (i.e. second segment limitation may be the limiting factor).

Therefore, the optimum configuration for flexible temperature may not be the same as the optimum configuration for tail clearance.

The flight crew should be aware that the highest flaps configuration provides the highest tail clearance.

SHOCK ABSORBER OLEO INFLATION

The correct extension of the main landing gear shock absorber (and therefore the nominal increase in tail clearance during rotation) relies on the correct inflation of the oleos. An under inflated oleo-pneumatic shock absorber will decrease the tail clearance.

The verification of the oleo-pneumatic shock absorbers is performed by the maintenance personnel. There are no means to check that the pressure is correct, during the pilot external inspection. However, the flight crew should check for asymmetry between both landing gears, and for any visible hydraulic leak.

CROSSWIND

In the case of crosswind, the flight crew should minimize lateral inputs on ground and during rotation, in order to avoid spoilers extension. If the spoilers are extended on one wing, there is a reduction in lift combined with an increase of drag, and therefore, a reduction in tail clearance and an increased risk of tail strike.

LANDING RISK FACTORS:

Any one of these four landing risk factors may precede a tail strike:

- Unstabilized approach.
- Holding off in the flare.
- Mishandling of crosswinds.
- Over-rotation during go-around.

A tail strike on landing tends to cause more serious damage than the same event during takeoff and is more expensive and time consuming to repair. In the worst case, the tail can strike the runway before the landing gear touches down, thus absorbing large amounts of energy for which it is not designed. The aft pressure bulkhead is often damaged as a result.

Unstabilized approach

An unstabilized approach appears in one form or another in virtually every landing tail strike event. When an aircraft turns on to final approach with excessive airspeed, excessive altitude, or both, the situation may not be under the control of the flight crew. The most common cause of this scenario is the sequencing of traffic in the terminal area as determined by air traffic control.

DFDR data show that flight crews who continue through an unstabilized condition below 500 ft will likely never get the approach stabilized. When the aircraft arrives in the flare, it invariably has either excessive or insufficient airspeed, and quite often is also long on the runway. The result is a tendency toward large power and pitch corrections in the flare, often culminating in a vigorous noseup pull at touchdown and tail strike shortly thereafter. If the nose is coming up rapidly when touchdown occurs and the ground spoilers deploy, the spoilers themselves add an additional noseup pitching force. Also, if the aircraft is slow, pulling up the nose in the flare does not materially reduce the sink rate and in fact may increase it. A firm touchdown on the main gear is often preferable to a soft touchdown with the nose rising rapidly.

Holding off in Flare

The second most common cause of a landing tail strike is a long flare to a drop-in touchdown, a condition often precipitated by a desire to achieve an extremely smooth landing. A very soft touchdown is not essential, nor even desired, particularly if the runway is wet.

Trimming the stabilizer in the flare may contribute to a tail strike. The PF may easily lose the feel of the elevator while the trim is running; too much trim can raise the nose, even when this reaction is not desired. The pitchup can cause a balloon, followed either by dropping in or pitching over and landing flat. Flight crews should trim the aircraft in the approach, but not in the flare itself, and avoid "squeakers," as they waste runway and may predispose the aircraft to a tail strike.

Mishandling of crosswinds

A crosswind approach and landing contains many elements that may increase the risk of tail strike, particularly in the presence of gusty conditions. Wind directions near 90 deg to the runway heading are often strong at pattern altitude, and with little headwind component, the aircraft flies the final approach with a rapid rate of closure on the runway. To stay on the glidepath at that high groundspeed, descent rates of 700 to 900 ft (214 to 274 m) per minute may be required. Engine power is likely to be well back, approaching idle in some cases, to avoid accelerating the aircraft. If the aircraft is placed in a forward slip attitude to compensate for the wind effects, this cross-control maneuver reduces lift, increases drag, and may increase the rate of descent. If the aircraft then descends into a turbulent surface layer, particularly if the wind is shifting toward the tail, the stage is set for tail strike.

The combined effects of high closure rate, shifting winds with the potential for a quartering tail wind, the sudden drop in wind velocity commonly found below 100 ft (31 m), and turbulence can make the timing of the flare very difficult. The PF can best handle the situation by exercising active control of the sink rate and making sure that additional thrust is available if needed. Flight crews should clearly understand the criteria for initiating a go-around and plan to use this time-honored avoidance maneuver when needed.

Over-rotation during Go-around

Go-arounds initiated very late in the approach, such as during flare or after a bounce, are a common cause of tail strike. When the go-around mode is initiated, FD immediately commands a go-around pitch attitude. If the PF abruptly rotates into the command bars, tail strike can occur before a change to the flight path is possible. Both pitch attitude and thrust are required for go-around, so if the engines are just spooling up when the PF vigorously pulls the nose up, the thrust may not yet be adequate to support the effort. The nose comes up, and the tail goes down. A contributing factor may be a strong desire of the flight crew to avoid wheel contact after initiating a late go-around, when the aircraft is still over the runway. In general, the concern is not warranted because a brief contact with the tires during a late go-around does not produce adverse consequences. Airframe manufacturers have executed literally hundreds of late go-arounds during autoland certification programs with dozens of runway contacts, and no problem has ever resulted. The aircraft simply flies away from the touchdown.

Tail strike prevention should be part of the recurrent training program due to the fact that many flight crew actions can be improved to help minimize the risk of a tail strike.

Airbus has released a new document, in electronic format called Tail strike Avoidance e-briefing.

The Airbus e-briefing provides various types of information in a single document, for pilot self-education and/or instructors briefing, including: Text, video (e.g. rotation technique), PowerPoint presentations and audios.

Relevant technical data in the Flight Crew Operating Manual (FCOM), such as aircraft geometry limits or pitch attitude after liftoff, also provides an awareness of the aircraft characteristics, which helps to avoid a tail strike.

PHOTO OF THE MONTH

Mexicana A320 tail strike

In May 2005, at the Licenciado Benito Juarez International, Mexico City(MEX/MMMX) Mexico, a Mexicana Airbus A320-231 had a powerful rotation during takeoff resulting in a tail strike.