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Loss of Control related to Angle of Attack

Background

Several incidents have occurred where aircraft ended up in upsets, in some cases leading to loss of control accidents. These eventsoften involved aircraft still being technically capable of safe flight. To prevent these incidents and accidents, upsets and loss of control awareness have to be addressed. Loss of control is defined as any state of the aircraft that it was not intended to be in. This paper deals with upsets and loss of control related to angle of attack, possibly leading to a stall. From here on this is referred to as Loss of Control - Angle of Attack (LoC-AoA).

Prevention of Loss of Control related to Angle of Attack

The main cause of LoC-AoA is flight control inputs (or the lack of flight control inputs) that are not appropriate for the situation the aircraft is in. These control inputs can be manual or auto-flight inputs. In the case of auto-flight, flight control law degradation on a fly-by-wire airplane can change flight control sensitivity, increasing the chance of inappropriate inputs. Two scenarios can lead to the before mentioned inappropriate manual or auto-flight flight control inputs. Either the pilots do not identify the situation they're in, or they do identify the situation but are unaware of the correct flight control inputs required to regain control of the aircraft.

As a consequence, prevention of a LoC-AoA incident is twofold. The first step is to recognize and identify the condition correctly. The second step is to fly the aircraft out of the condition correctly. Both these steps demand clear and intuitive presentation of flight information and guidance. This enables a timely response by the pilots to the condition they're in, and prevents incorrect control inputs. In addition, adequate training of pilots is required to obtain and maintain the required level of skill to deal with LoC-AoA.

To summarize, preventing LoC-AoA is accomplished by adequate training, and providing clear and intuitive display of flight information and guidance.

LoC-AoA training

LoC-AoA events are rare. Consequently LoC-AoA training is important during initial as well as recurrent training.
The following elements should be included in the training:

- Manual flying skills, i.e. pitch-power flying
- Awareness of flight envelope limits, i.e. high altitude aerodynamics and low speed regime
- Specific high altitude flying skills and knowledge of flight control deflection effects, i.e. spoiler pitch up effect
- Interpretation of flight information presented, i.e. stall warnings and AoA-based indications, such as pitch limit indications and flight path vectors in combination with pitch angle
- Stall margin awareness at low and high altitude
- Upset and stall recovery procedures at low and high altitude
- Knowledge of flight control characteristics, i.e. elevator authority and pitch trim behavior
- Knowledge of flight control law degradation and flight control sensitivity change
- Startle factor

Flight information and guidance

Flight information regarding aircraft energy state can aid pilots in recognizing and recovering from LoC-AoA. Identifying an excessive increase in AoA will aid the pilot in choosing the proper flight control inputs required. Recovery from an excessive AoA requires unloading the airplane by decreasing the AoA. So a primary flight parameter during an upset is AoA. As a result, prevention of LoC-AoA demands a clear and intuitive display of AoA-based information.

AoA can be presented on the flight deck in two ways, directly and indirectly. The direct way is by means of an AoA indicator that displays the actual AoA. In most large aircraft AoA is not presented directly on the flight deck. It is presented indirectly, and different manufacturers have different ways to do this. Indications such as a pitch limit indicator and colored speed tapes provide

limits of the flight envelope, based on AoA. Therefore they present information based on angle of attack without presenting the actual AoA itself. In addition, aural warnings related to the stall warn the pilots based on AoA.

AoA indicator

The advantage of an AoA indicator is that it directly displays the main flight parameter involved to recognize and recover from the LoC-AoA condition. Therefore it might seem contra-intuitive not to provide an AoA-indicator on the flight deck. However several drawbacks of an AoA-indicator can be identified:

- The majority of the pilots are not trained in using an AoA indicator.
- In the normal flight regime, an AoA indicator is not used. As a consequence, the use of an AoA indicator will not become second nature to the current generation of pilots, even after training. It is therefore likely not to be used in high workload situations, such as loss of control. A stall margin indicator would be more useful and could be used continously.
- A significant amount of flight information is already available on the flight deck. Any extra parameter such as AoA could lead to confusion.
- The interpretation of an AoA indicator is not intuitive. A mind step has to be made before the use of AoA information can be translated into action.
- In most modern day flight decks, AoA information is already available in the form of a flight path vector in combination with the aircraft symbol. The pitch limit indicator also provides AoA information, as well as stall warning systems.
- To display the true AoA the AoA indicator requires Mach compensation which relies on an air data system input.

As a result of this list of drawbacks, a better solution than an AoA indicator can be found to deal with LoC-AoA. If no direct AoA indicator is available on the flight deck, another way of displaying AoA information is required. The solution is found in the display of AoA-based information and guidance.

Display of AoA-based information and guidance

The indirect display of AoA, referred to as AoA-based information, can be designed in various ways. The advantage is that this design can be tailored to provide clear and intuitive guidance to deal with LoC-AoA. In addition it can complement the way modern day pilots use the information presented on the PFD, instead of adding a new flight parameter to their scan. Examples of a guidance cue on the PFD, possibly using color-coding, are:

- A pitch limit indicator
- A flight path vector showing flight envelope limitations
- Presentation of a “fly-to” or “fly-away” zone

These AoA information and guidance cues can be used to present information useful to prevent LoC-AoA, as well as guidance to recover from LoC-AoA. A disadvantage is that there is no common standard yet for such a display. Pilots flying different types of aircraft during their career may have to adapt to different displays as long as there is no standardization. The quality of the design will minimize this drawback. Consequently, human factors, different backgrounds and experience levels of pilots, and standardiztion among manufacturers are issues that have to be addressed while deciding on the way to go. The design of these AoA-based cues will determine their usability, and consequently their success.

Summary

Preventing LoC-AoA is essential to reduce a major contributing factor of incidents and accidents. The way to go is twofold:

1) train pilots on AoA behavior not simply it’s definition, and

2) design the presentation of AoA information and guidance so that it is intuitive and independant of the airplane’s air data system.

The direct display of AoA using an AoA indicator has several draw backs and is not desired. A clearer and more intuitive display of AoA-based information and guidance will help in the recognition and recovery of upsets due to excessive AoA.