2016 4th International Conference on Methods and Systems of Navigation and Motion Control (MSNMC) Proceedings pp.271-274

Minimum Landing Speed Criteria Generated by Means of Avionics

O.O. Chuzha
Avionic Department
National Aviation University
Kyiv, Ukraine
achuzha@ukr.net

***Abstract*—This paper deal with stall warning system critical flight modes. Special focus was on critical conditions warning indication during landing. Recommendations about the basic parameters required for display warning critical conditions whilst landing was proposed.**

***Keywords*—lift; stall; angle of attack; lift coefficient; stall speed; angle of roll; weight of the aircraft**

I. Introduction

Flight safety is the basic quality indicator in civil aviation. It supposes constant hazard identification and management of risk factors. Hazards during landing can be considered as rolling out the aircraft on flight critical modes that at low altitudes and low velocity conditionals cause aircraft stalling risk.

Prevention control of going beyond the critical modes requires installation avionics systems on board the aircraft that provides the crew alarm to approach the maximum permissible parameters of the flight, and in some cases make a correction to the aircraft control system to avoid entering into the critical modes.

II. Problem Statement

Analysis of flight accidents statistics of recent years shows a large number of accidents, which may arise from pilot errors at flight critical modes. Loss of control in flight and while landing approach were the main causes of aviation accidents during this period [1].

It is known that lift (L) is a result of pressure differences and depends on air density (ρ), airspeed (V) airfoil shape (S) and lift coefficient (C_L) in accordance with the conditions [2]:

$$L = 1/2 \rho V^2 S C_L.$$

In addition, overload (n) is a parameter that regards all forces array acting on an airplane and characterize it controllability.

Lift penalty to the level of less than the aircraft gravity force leads to height loss, and lift sharp fall cause stall. Therefore, one of the main dangers for the plane is to reduce air velocity relative to the lift reduction and its stalling due to loss of speed or increase of the angle of attack above its critical value (Fig. 1).

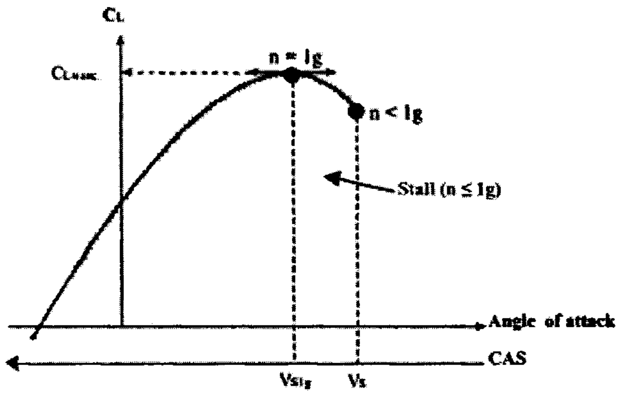

Fig. 1. Lift coefficient.

Stall speed (V_S) is the speed of horizontal flight, where there are signs of intense turbulence of the air flow on the wing due to the exit of the aircraft at the critical angles of attack (α_S) with a decrease in the speed of flight (Fig. 1).

To improve flight safety criteria necessary to analyze factors affecting stall during landing and types of informing the pilot of the approach to the regime of stalling.

III. Problem Solution

The aircraft landing consists of descent stage and landing distance (Fig. 2).

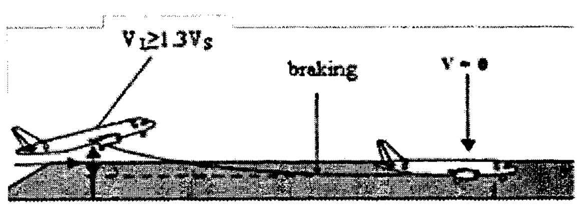

Fig. 2. Airplane landing scheme.

During the descending aircraft moves along the inclined path down from the height of the approach to the landing height with constant speed (V_L) which exceeds the stall speed (V_S) based on the following conditions:

$$V_L \geq 1.3 \cdot V_S$$

Factors of risk that lead to height loss and stall at low altitudes during approach are:

- losing ground speed;
- excess of vertical speed;
- critical angles of attack;
- excess of weight (W);
- critical angles of heel;
- engines nose-up moment;
- the impact of weather conditions.

If speed reduced, the lift will decrease. To maintain it at the same level, it is necessary to increase the lift coefficient (C_L), i.e. the angle of attack (α). Therefore, the lower speed should be the more angle of attack until the lift coefficient reaches a critical maximum value ($C_{L\max}$). A further angle of attack increase will lead to a sharp reduction in the lift and stall of an aircraft. In this case stalling speed will be determined by:

$$V_S = \sqrt{\frac{2L}{\rho C_{L\max} S}}.$$

Hence, aircraft wing area and air density has no significant impact on the stall speed.

Approach to excess ground speed leads to intensive speed bleed off on the glide path by interceptors applying and the angle of attack that can lead to failure below the glide path and enter the critical angles of attack.

Ground speed loss on the glissade and flaring-out will lead to the loss of lift and control torque moments, and as a result the plane goes out of control and stalls.

Rate of descent excess (VS_L) leads to subsidence of the aircraft during the alignment resulting touching the ground outside the runway or withdrawal of aircraft critical angles of attack under vertical speed retardation.

The following condition should be for airplane flight without height loss, i.e. with a constant vertical overload (n_{ZW}):

$$n_{ZW} = \frac{L}{W} = 1.$$

Approach to exceeded landing weight ($n_{ZW} < 1$) increases the estimated stalling speed (V_{SR}) under the conditions:

$$V_{SR} = \frac{V_{CL\max}}{\sqrt{n_{ZW}}},$$

so the minimum landing speed ($V_{L\min}$) should also be increased.

This factor is important for landing with plenty of fuel, hence during landing after the trip the aircraft weight may decrease in 1.2–1.7 times.

Therefore, the aircraft weight (W_L) increase during landing leads to the desired increase in lift, which will increase the stall speed:

$$V_{SR} = V_L \sqrt{\frac{W_L}{W_C}}.$$

Critical roll angles (γ) affect aircraft lift during landing. During rolling the lift (L) is composed of such components as the vertical one (L_N), compensating the weight of the aircraft which becomes lower, i.e. the plane begins to lose altitude with sliding toward the angled wings, dangerous at low altitudes (Fig. 3) therefore necessary to increase lift. For example, with the roll angle $\gamma = 45°$ height should be increased in 1.41 times to stabilize the lift.

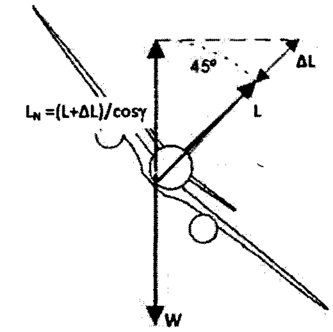

Fig. 3. Lift-roll angle relationship $L_N = f(\gamma)$.

Lift increase is made by increasing the angle of attack. The greater the lift, the higher normal overload is. The overload should also rise with the roll angle increase. Therefore, the rise with the presence of lift roll at constant altitude depends on the roll angle (normal overload). Overload value does not affect the value of the critical angle of attack.

A sharp thrust increase in aircraft engines with lower placement of the power plant can cause going into the critical angles of attack. While missed approach procedure during an unsuccessful landing the engines of the aircraft transferred to the maximum thrust. In this case, in addition to the current angle of attack it is needed for the climb-included angle of attack set up by an engine's nose-up moment (M_{ZT}). This leads to an excess of the critical angle of attack (Fig. 4) under control and loss of height, which increases the stall speed.

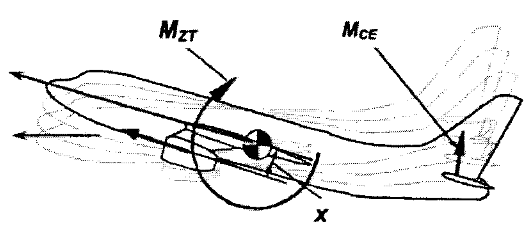

Fig. 4. Pitching nose up.

Weather conditions also influence on the change of stall speed. Any contamination of the wing surface with snow, ice or frost modifies its aerodynamic profile, which leads to changes in lift coefficient and therefore stall speed. For example, icing of the wing leads to a reduction lift coefficient ($C_{L\max}$) and increases stall speed by 30%. The presence of ice leads to increased weight of the aircraft, which also increases the stall speed.

IV. Results

Thus, the critical angles of attack during landing are the result of ground speed excess or vertical speed (VS_L) during landing, and can result in loss of lift and stall the aircraft at low altitudes.

The weight of the aircraft does not effect on the critical angle of attack change, but the effects on the vertical overload (n_{ZW}). For a rough calculation the following pattern is used: an aircraft weight change of 20% leads to a stall speed change of 10% (Fig. 5).

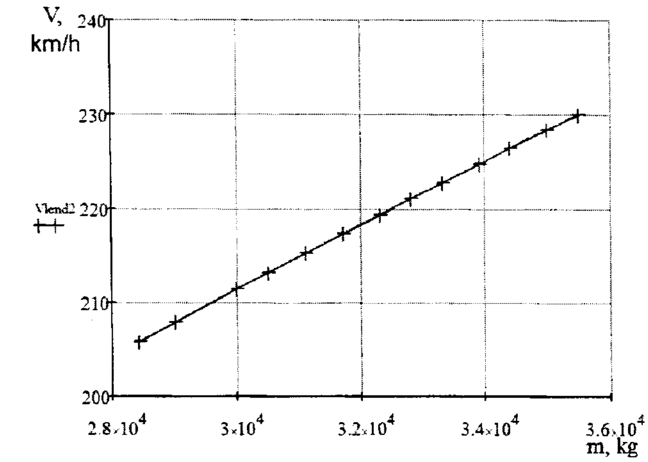

Fig. 5. Dependence landing speed of the weight of the aircraft.

In rectilinear horizontal flight with maximum lift coefficient ($C_{L\max}$) it is impossible to have the angle of heel and maintain altitude simultaneously. Trying to increase the lift will increase the stall speed according to conditions:

$$V_{SRoll} = \frac{V_{SR}}{\sqrt{\cos\gamma}}.$$

For example, if the calculated stall speed of the aircraft (V_{SR}) is 150 units, with the roll presence there will be following the law (Table I).

TABLE I. STALLING OUT SPEED – ROLL ANGLE RELATIONSHIP

γ (AOR), degrees	25	30	45	60
V_{SR}, knots	158	161	178	212

Therefore, during landing it is essential to avoid large angles of roll, especially at low altitudes and speeds. In order to retain the aircraft in horizontal flight with increasing roll angle of 15 degrees, lift does not change significantly, and after 30 degrees lift must be sharply increased (Fig. 6).

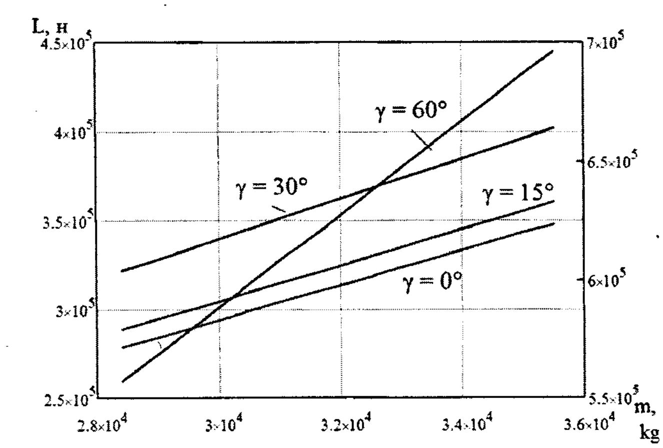

Fig. 6. Dependence of the lift of the aircraft weight and the roll angle.

Avionics manufacturers partly take into account these criteria and according to their importance is placed on primary flight displays (PFD) a warning alarm in the cockpit.

In aircraft manufacturing countries of the CIS basic parameters of the display, informing the crew of the approach to critical flight modes are the angle of attack and overload (Fig. 8), and foreign manufacturers inform the crew through the formation of stalling the minimum speed (Fig. 9). However, these options do not fully take into account criteria such as the weight of the aircraft and engines pitch-up time. It is therefore necessary to increase the number of electronic information displays based on these criteria especially during landing.

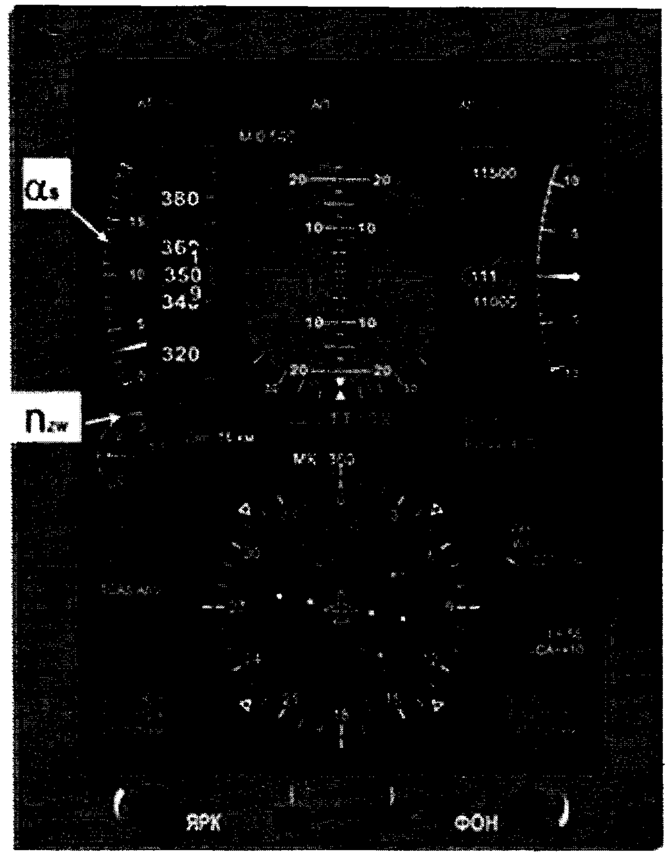

Fig. 8. Location a warning alarm on PFD Antonov An-148.

Thus, for the prevention of dumping, it is advisable to cover the information on the display:

- the minimum speed stall;
- the current angle of attack;
- current overload.

V. CONCLUSIONS

Thus, almost all the risks that lead to the aircraft stalling on the descent and landing stages are related to the critical angle of attack and minimum speeds range. Therefore, to eliminate these risks constant monitoring of minimum landing speed and stall speed are required. For this purpose modern aircraft avionics system should include stall warning system, which is used to calculate the following speed criteria:

- calculated air speed (V_{CAS});
- angle of attack (AOA);
- slats and flaps position (or wings mechanization);
- current overload;
- current weight of the aircraft;
- angle of roll (AOR);
- the level of engine thrust ($N1$ and $N2$);
- wings and engine anti-icing systems status (TAI).

The result of research should be installed into a warning system to inform the pilot during approach to stall, considering dangerous criteria such as minimum landing speed and current overload and the current angle of attack.

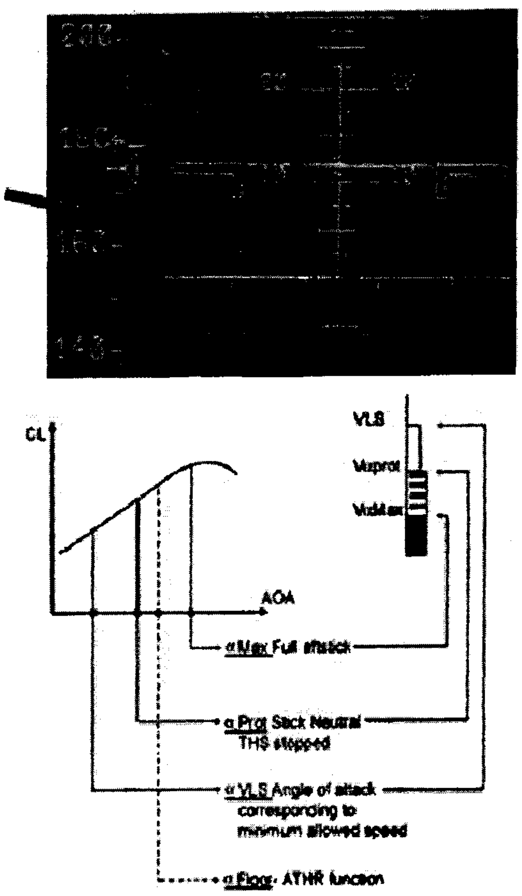

Fig. 8. Location a warning alarm on PFD Airbus A320.

REFERENCES

[1] ICAO Safety Report. Edition. International Civil Aviation Organization 999 Boulevard Robert-Bourassa Montréal, QC, Canada H3C 5H7. 2016, p. 24.

[2] Flight Operations Support & Services Airbus S.A.S. 31707 Blagnac Cedex, France. 2007, p. 211.

[3] V. Kastorovsky, "Fundamentals of aerodynamics and dynamics of flight." Riga: Transport and Telecommunication Institute, 2010. p. 105

[4] M. Kotik and V. Filipov, "Flying in extreme conditions." Moscow, Military Publishing, 1977, p. 239.

[5] A. Chuzha, G. Polozhevets, and I. Donchenko. "Informational services for crew about minimal critical flight velocities." The sixth world congress "Aviation in the XXI-st century", "Safety in aviation and space technology." September 23-25, 2014. pp. 3.4.1-3.4.3.

[6] O.O. Chuzha and O.H. Sytnik, "Visual optoelectronic systems of landing aircraft." Materials of the XI International conference "AVIA 2013," vol. 2, Kyiv, NAU, 2013, pp. 13.45-13.48.