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AEROPLANE STALLS AND LOSS OF ALTITUDE

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Abstract. The aim of this study is an experimental verification of loss of altitude during a stall which is performed on a specific aeroplane type in a flight simulator environment. Also, the paper deals with a methodology how to control an aeroplane entering stall conditions and its recovery in the flight simulator. An experimental verification of altitude loss during the stall is a part of this paper too. Values collected from various measurements of loss of altitude during stalls were recorded into specific tables. Recorded values were diversified according to specific stall types.

Keywords: aeroplane stall, aerodynamics principles, wing mechanism, DCS World

1. INTRODUCTION

The initial chapter of this paper defines aeroplane stall conditions, and approved procedures for its recovery. This study´s outcome is defined as a methodology compilation describing the situations of aeroplane stalls and their subsequent recovery in the flight simulator, and where loss of altitude is verified. The aim of this paper is completed methodology for Yak-52´s stall performance and its recovery in the digital combat flight simulator DCS World. Final parts of the paper deals with loss of altitude data records, collected during normal and sharp stalls, which were performed and measured in the simulator browsed by Tacwiev analytical software. This paper´s benefits, utilized either in a simulator or live environment, are procedures for pilots who get learnt how to perform aeroplane stalls safely and early recognize becoming threat signals.

2. DEFINITION OF STALLING

The loss of wing force is caused by aeroplanes´ entering a high angle of attack and when its critical limit is overstepped. Expanding angle of attack resulting in ceasing of airflow to flow smoothly aerofoil and then becomes extremely turbulent. This is leading in airflow separation, loss of lift and increased drag [1].

A sudden loss of lift might cause catastrophic circumstances, especially when occurred without any prior alert. It is understandable, that aeroplanes´ stalling characteristics usually depend on wings´ geometry and aerofoil shapes. A distribution of lift power on a wing depends on geometrical wing shape.

Figure 1 Air flow separation over an aeroplane´s wing [1]

A pilot must recognize the flight conditions that are conducive to stalls and know how to apply the necessary corrective action. This level of proficiency requires training to recognize an impending stall by sight, sound, and feel [2].

Stalls are usually accompanied by a continuous stall warning for airplanes equipped with stall warning devices. These devices may include an aural alert, lights, or a stick shaker. The devices turn on at the conditions when the aeroplane enters the critical angle of attack. Some types of light sport aeroplanes are not equipped with such devises. In these cases, a pilot must fully rely on his sensual perception.

Feel
The pilot will feel control pressures change as speed is reduced. With progressively less resistance on the control surfaces, the pilot must use larger control movements to get the desired aeroplane response. The pilot will notice the airplane's reaction time to control movement increases. Just before the stall occurs, buffeting, uncommanded rolling, or vibrations may begin to occur [2].

Vision
Since the aeroplane can be stalled in any attitude, vision is not a foolproof indicator of an impending stall. However, maintaining pitch awareness is important [2].

Hearing
As speed decreases, the pilot should notice a change in sound made by the air flowing along the aeroplane structure [2].

Kinaesthesia
The physical sensation (sometimes referred to as "seat of the pants" sensations) of changes in direction or speed is an important indicator to the trained and experienced pilot in visual flight. If this sensitivity is properly developed, it can warn the pilot of an impending stall [2].

2.1. Stall and the methodology of recovering

A stall is an aerodynamic condition which occurs when smooth airflow over the airplane's wings is disrupted, resulting in loss of lift. The laminar airflow separates while the aeroplane reaches critical angle of attack. Exceeding the critical angle of attack results in:

- drag vibrations sensed on the flight deck instruments,
- noticeable drag increase,
- centre of gravity moved backward,
- significant loss of lift, resulting in loss of altitude despite pilot´s effort to trim the aeroplane nose up,
- eventual rolling and spinning occurrences caused by uneven volume of lift power under right and left wing,
- pitching down flightpath changing air flow through the horizontal stabilizer and resulting in nose down conditions. (the occurrence is subject of aeroplane type and centre of gravity position) [3].

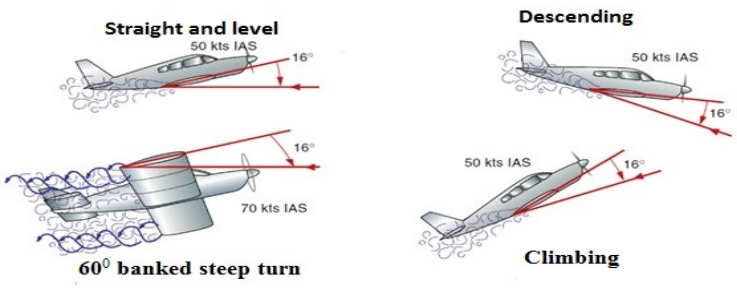

Figure 2 An aeroplane in the critical Angle of Attack (AOA) [1]

The stall situations always impend after an aeroplane has passed the critical angle of attack, regardless its speed and flight level. A pilot can extend angle of attack by pulling back the control wheel. This action reduces aeroplane´s speed too. Such situations are standard in cases of:

- slow flight,
- spin recovery,
- yawing, and
- landing.

A vertical wind flow might have a slight effect on a relative airflow across wings and extend angle of attack far behind its critical figures [3].

Stalling speed

The initial stalling speed is defined as a speed at the moment when aeroplane, within its maximum take-off weight and standard configuration, impends a stall. Existing published stalling speed rates are for reference reasons only due the fact, that the stall always commencing at the constant angle of attack, while indicated flight speed is neglected. It has been proved that banking turns, situations of power-off stall recovery, wings contamination (e.g. ice) , and wings surface fractions, can contribute to an acceleration of aeroplanes´ stalling speed [4].

2.2 Types of stalls and its recovering

Normal stall

A normal stall is typical for aeroplanes flying in the horizontal flight configuration. The normal stall is initiated in a level flight by reducing the engine torque to idle and gentle pulling back the control wheel, while maintaining desired former altitude. By increasing the angle of attack, an aeroplane loses its flight speed till approaches the stall speed. Gradual airspeed decays, and results in loss efficiency of elevators to control fades proportionally and decreasing aeroplane speed. Loss of speed is sensed as a control wheel and other flight deck instruments vibrate. This situation is invoked due a turbulent airflow across the aerofoils. Once this situation has occurred, the aeroplane turns to a stall in a few seconds. The aeroplane's nose drops down below the horizon. Hereby, it is recommended for a pilot to perform descending by abruptly moving forward the control wheel and attempting a 30^0 to 40^0 pitch angle. Simultaneously, the pilot must push forward the control wheel what maximises engine power thrust. As soon as the aeroplane riches recovered conditions, and adequate airspeed, the pilot must steadily pull back the control wheel, and restore the aeroplane to desired level flight, and set engines power to a cruising speed, or exhaust accumulated speed for aeroplane´s pitching up. In cases, the aeroplane indicates various side banks, the pilot must press the foot pedal located opposite side to aeroplane´s banking. It is very important for the pilot to avoid the aeroplane control by flaps, as this manoeuvre in combination with retained low cruising speed, could result in aeroplane´s upset flight, for example a wing stall or spin.

Sharp stall

A sharp stall is very similar to the normal stall. But there is one significant variation noted when the aeroplane is approaching stalling speed, the overall process of loss of altitude and continuous progress to the stall are faster. The sharp stall is configured in a horizontal flight, where an engine is set to pitching up phase. As soon as the stalling speed is achieved, the aeroplane is set to a 45^0 pitch angle. This manoeuvre accumulates exceeding altitude beside rapid loss of speed. The pilot must concentrate on trimming the aeroplane in the level flight by flaps. In slow flight situations, this manoeuvre is completed by aeroplane's rudder. Consequently, upon achieving desired flight speed, the pilot must set the engine torque to idle and hold the aeroplane in a constant pitching up phase. Due aeroplane´s impending to the stall speed, separation of airflow on the laminar areas are being recognized. Aeroplane's nose drops over the horizon once the speed is lost and the stall is entered. At the moment when the aeroplane's nose is passing the horizon, the pilot must increase to a maximum thrust engine power. Also, at very this moment, the pilot must push the control wheel and hold a 30^0 to 40^0 pitch angle. As soon as the aeroplane achieves required speed, the pilot must steadily pull back the control wheel, and restore the aeroplane to desired horizontal flight. After this manoeuvre, the recovery process is completed by setting engines to a standard flight regime.

3. EXPERIMENTAL VERIFICATION TESTS OF LOSS OF ALTITUDE DURING STALLS

This chapter deals with a methodology illustrating Yak-52´s impending to a stall flight and its recovery in DCS World flight simulator. Achieved results regarding measured loss of altitude are processed in Tacview application. Also, this chapter outlines information how to control Yak-52 to stall flights and its recovery, also in the simulator environment. Practicing aeroplane stalls in the simulator is very worthy for pilots, as they get learnt normal and sharp stall situations and threats to fly an aeroplane into stalls. Yak-52 is approaching the stall in a clear configuration and determined speed of 110 km/h (59 kt). This speed might vary to 100 km/h (54 kt) in cases when flaps are deployed. In relation to aeroplane weight, the process of entering the stall depends on the angle of attack. The higher angle of attack is, the faster is aeroplane's approach to the stall.

3.1. Normal stall methodology

A pilot must reduce the engine torque to idle while an aeroplane trimmed in the horizontal flight and altitude of 1000 m (3280 ft) and IAS 250 km/h (135 kt). The pilot is responsible to hold the exact altitude until stalling speed attained. Alongside flying speed is decreasing, the pilot must gradually pull back the control wheel. This action extends the angle of attack, and balance loss of speed by increasing of the lift factor. As the angle of attack is continually extending, the centre of gravity is moved forward, and separate laminar airflow is recognized across wings. In this situation, use of aeroplane´s rudder is ineffective. The pilot must hold this flight conditions until IAS 110 km/h (59 kt). Aeroplane´s banking is prevented by use of the direction rudder. This also preserves the aeroplane from entering in spins. As soon as stalling speed is achieved for the specific configuration, aeroplane's nose pitching down below the horizon, and the aeroplane flies into the stall. The pilot must respond immediately, and take actions as follows: abruptly move forward the control wheel and attempt a 30^0 to 40^0 pitch angle, and increase to maximum thrust engine power. As soon as IAS 140/ km/h (76 kt) achieved, the pilotage becomes effective again, and the pilot trims the aeroplane by pulling the control wheel until the horizontal flight achieved.

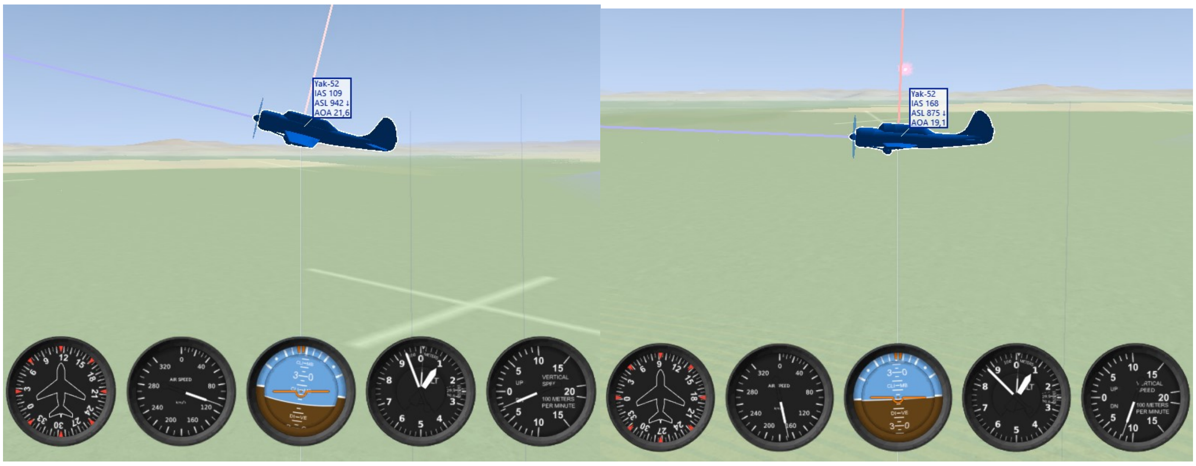

Figure 3 Initial normal stall and recovery [1]

3.2. Sharp stall methodology

The initiate phase of a sharp stall, which similar is to a normal stall, is the horizontal flight. The pilot maintains the horizontal flight, but comparing to the normal stall, engine is set to an ascending flightpath. The pilot holds the horizontal flight until IAS achieves 270 km/h (146 kt). As soon as required speed has been achieved, the pilot pulls back the control wheel and trim the aeroplane to a 45° pitch. After flight speed of 200 km/h (108 kt) has been achieved, the pilot reduces the engine torque to idle. After the aeroplane achieves stalling speed of 100 km/h (59 kt.), aeroplane´s nose dynamically bends over the horizon. The pilot recovers the aeroplane same as in case of the normal stall. The aeroplane conducts descending of a 30° - 40° angle. Simultaneously, the pilot pushes forward the control wheel, and sets maximum engine thrust. As soon as required airflow is recognized on the wings, and flight speed is 140 km/h (76 kt), the pilot trims the aeroplane to the horizontal flight, by gentle pulling back of the control wheel. Also, this situation refers to a fact that aeroplane´s banking (spinning) in the slow flight can be effectively prevented by using the rudder.

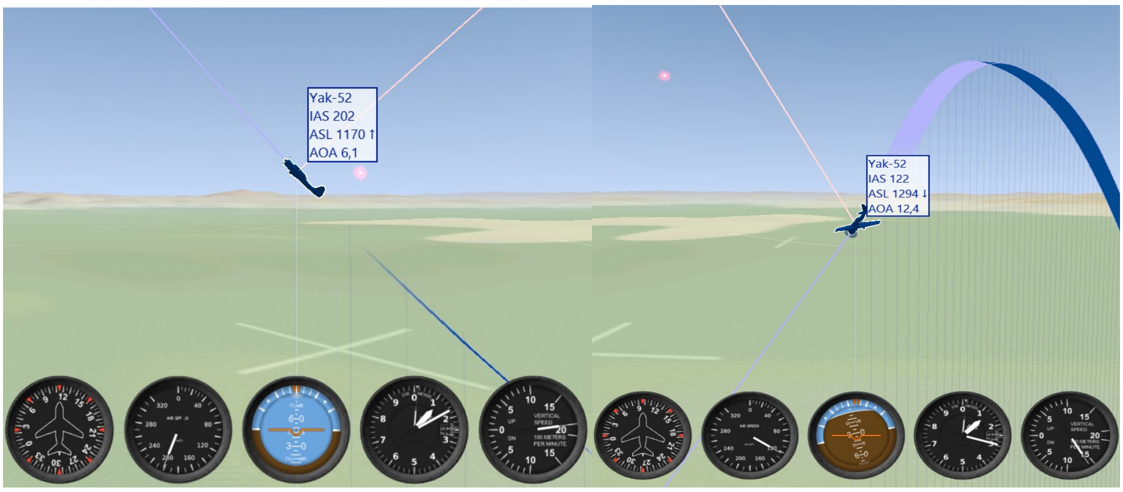

Figure 4 Initial sharp stall and recovery [1]

3.3. Experimental verification of stalling altitude loss

The experimental verifications of altitude loss during stalls were conducted by a clean configured aeroplane, in line with the methodology described in the Chapter 6.2. All experimental flights were operated by Yak 52 in the DCS World simulator. Aeroplane's altitude at the moment of entering the stall, and pitching down below the horizon, were recorded within the initial parts of the tests. As soon as the aeroplane´s recovery was completed, and the aeroplane trimmed to its horizontal flight, the aeroplane´ s altitude was measured second time. Loss of altitude was calculated as a subtraction between initial altitude and latter one. Altitude loss measured figures have been recorded in the tables as displayed in the Table 1 a Table 2.

Table 1 Loss of altitude data (in meters ´m´)

Measurement no.	1.	2.	3.	4.	5.
Normal stall	103 m	101 m	95 m	97 m	97 m
Sharp stall	127 m	127 m	123 m	135 m	130 m

Table 2 Loss of altitude data (in feet ´ft´)

Measurement no.	1.	2.	3.	4.	5.
Normal stall	338 ft	331 ft	312 ft	318 ft	318 ft
Sharp stall	416 ft	416 ft	403 ft	442 ft	426 ft

Measured values of stalling loss of altitude prove that stalls performed at height of 1000 m over the ground are considered safe. Required flight altitude should be necessarily held for training other Upset Flight situations such as half rolls, and spins. Above mentioned Upset Flight situations could become, if improper pilotage conducted, same as the manoeuvres when a pilot trying to trim slow flight by flaps.

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