STUDY OF LANDING TECHNIQUE DURING VISUAL APPROACH

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Abstract

The purpose of this paper is to focus on the landing technique during the visual approach, analyze the risk at landing and make instruction to avoid the risk especially for unexperienced pilots.

Airline has adopted several dozen of ab initio pilots every year and they normally become captains after flying about ten years as co-pilot. It is necessary in co-pilot for airline to make flight operations, maneuver technique and circumstantial judgment acquire effectively.

This study picks up the various risks at landing, analyzes the causes behind them using the flight simulator then makes the technique to avoid the risks. And we compared the landing technique of unexperienced pilot with that of experienced pilot by the analysis using Neural Network method and found this method is effective to the quantitative analysis of the part which the pilot processes sensuously at landing.

1. Introduction

With technological innovation, automatic landing and rollout is introduced into the civil aviation and executed in line operations if circumstance permits. However, all runways do not enable auto-landing and most of landings are made with manual operation of the pilot. In manual landing, pilot controls the aircraft taking into the aircraft conditions and estimating the aircraft movement, based on the visual information, aircraft controllability, aerodynamic characteristics and his experience, etc. These landing techniques are acquired through training and actual operation spending long period

We analyzed the landing techniques which veteran pilots acquire through experience, then evaluated those using B767 flight simulator. As a result, we divided the landing technique into three phases as follows and picked up remarkable items in each phase.

- Stabilized approach from 500ft to 30ft
- Flare technique
- Landing technique in the severe situation

Furthermore, we compared the landing technique of unexperienced pilot which that of veteran pilot by the analysis using Neural Network method.

2 Stabilized Approach from 500ft to 30ft

Smooth landing or not depends on the stability of the aircraft from 500 ft to 30 ft before touch down. The pilot decides the target approach speed based on the aircraft weight, landing flap and surface wind, then controls the aircraft on the desired path. The pilot monitors the outside view and the cockpit instruments, takes the corrective action if the aircraft sifts from the desired path. Followings are the key points to stabilize the aircraft smoothly.

2.1 Pilot Eye Position

The pilot adjusts his seat position to keep his eye position always same. This is because the pilot usually recognizes the change of path with the distance between glare shield and the runway or the horizon. When eye position is high, while insight of the runway becomes easy, the change of path becomes difficult to recognize. In addition, when eye position is low, it becomes the opposite.

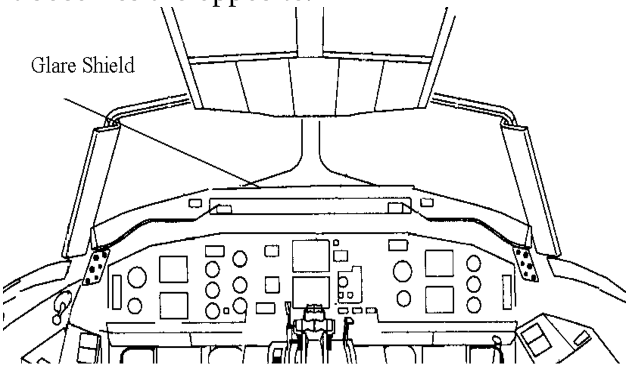


Fig. 1 View from Pilot

2.2 Initial Flight Path

The pilot knows the required the pitch angle and thrust empirically to maintain desired path. In order to stabilize the path the pilot keeps the wing level, controls the desired pitch angle, sets the thrust lever then turns the nose into the wind direction to overlap the aircraft track with the runway direction. After that, the pilot corrects the track on the localizer course or the runway centerline.

2.3 Setting of Trim

The aircraft stability increases by setting of accurate trim. The pilot takes the stabilizer trim at the half of expected trim first to prevent the over trim, then adjusts the trim after attitude is stabilized. Because there is time lag in operation of the stabilizer trim, the pilot controls the trim anticipating that time lag. In addition, the pilot adjusts the trim periodically because the required trim varies according to the change of speed. As for rudder trim, the pilot checks the trim stays at zero at the certain phase in descent.

2.4 Awareness of Path Change

When path is fixed, the distance between the glare shield and the runway do not change largely until low altitude. If the pilot pays attention to the outside view other than the runway, it is likely to recognize the change of path by the change of relative position relationship. In addition, the glide slope of ILS or PAPI information is effective if available.

It is necessary to pay attention that the displacement from the proper path differs depending upon the aircraft position even if the glide slope deviation in cockpit instrument or PAPI information is same. The 1 dot deviation of glide slope in instrument means 0.35 degrees deviation from the proper path, for instance, when the glide slope deviation in instrument shows 1 dot below at 500ft descending 3 degree path, the aircraft flies approximately 50ft below the proper path, and at 100ft, the aircraft flies 10ft below the path. The displacement of 1 dot deviation in instrument is approximately equal to the 1/10 of aircraft altitude. In other words, as the aircraft is descending and near to the runway, the significance of 1 dot deviation in instrument changes, it is necessary to take the corrective control considering this.

When the aircraft is near to the runway, the influence of the difference between the aiming point and the setting position of glide slope antenna or PAPI becomes remarkable. Because of this, the pilot changes the visual cue, i.e. runway marking, as the aircraft is near to the runway.

2.5 Corrective Control

The pilot recognizes the deviation from the proper path and the distance and time to the runway and considers when and how much the corrective control is required, then takes the corrective control. In this corrective control, the deviation of speed and path, thrust, sink rate at each altitude are checked, it is possible to take the next corrective control referring the previous control and totally the control is smooth. In addition, if the pilot grasps the appropriate time required for the speed change after the thrust controls and the altitude change during approach descent, it is effective to thrust control. The pilot finally checks the aircraft configuration by monitoring the speed and thrust when crossing the runway threshold. If the aircraft has the enough energy at this point, the flare will be stable.

3. Flare Technique

Even if the aircraft is stabilized to 30ft, the aircraft may land hard or float as the timing of flare, pitch up amount and its rate. In case of cross wind condition, the higher flare technique is required because it is necessary to control of lateral direction.
Followings are the key points at flare.

3.1 Shift of Aiming Point

The flare that the sink rate at touch down is zero is ideal but it is not realistic. The pilot changes the flight path to shallower one slowly by shifting the aiming point to the inner from 30ft. This is time, it is important to recognize the change of pitch angle and flight path utilizing the outside view and the automatic altitude callout effectively. For instance, if it excessively concentrates on the aiming point, the visual information such as the extent of the runway edges, angle and size of the touch down zone marking and the horizon etc. is not utilized, then it is difficult to do the stable flare.

3.2 Nose Down Moment at Flare

As the aircraft gets near to the runway, the ground effect works in the aircraft. This increases the lift of the wing and makes the nose down moment. This moment negates the nose up moment by pitch up control at flare, although the pilot pulls the control column, the pitch attitude does not increase from expectation. In addition, the influence is not large, but nose down moment works by reducing the thrust. The pilot controls the column at flare considering these effects.

3.3 Time Lag at Pitch Up

When the pilot pulls the column, the nose up moment works on the aircraft first, then the sink rate reduces. The time lag between the pitch control and the change of aircraft attitude shows in Fig.2.

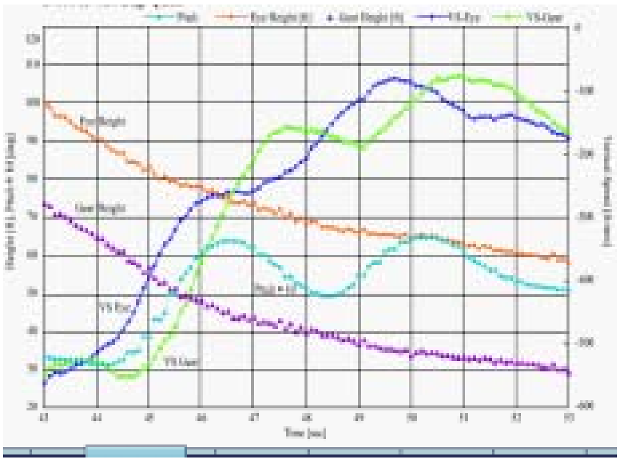


Fig.2 Time Lag of Pitch Up Control and Aircraft Attitude Change

3.4 Effect of Weight

When the approach speed changes with the aircraft weight, sink rate, which means the approaching rate to the runway, changes (Table 1).

Wt [klb]	Flap	TAS [kt]	Wind	TCH [ft]	PCH [deg]	Vert G	V/S ft/m	TDP [ft]	A/S [kt]
280	25	Vref+5	H	42	2.3	1.2	250	1485	148
240	25	Vref+5	H	45	3	1.5	300	2272	136
240	25	Vref+5	H	45	0.8	1.4	200	2014	136
280	25	Vref+5	T	47	5.2	1.8	400	758	140
280	25	Vref+10	T	46	4	2.1	600	893	144
240	25	Vref+5	T	42	3.2	2.5	750	724	128
240	25	Vref+10	T	44	4.1	1.6	500	704	135

TAS: Target Approach Speed, TCH: Threshold Crossing Height,
TDP: Touch down Point, A/S: Air Speed at Threshold

Wind: H: 10kt Head Windshear below 100ft

T: 10kt Tail Windshear below 100ft

Table 1 Sink Rate VS Aircraft Weight

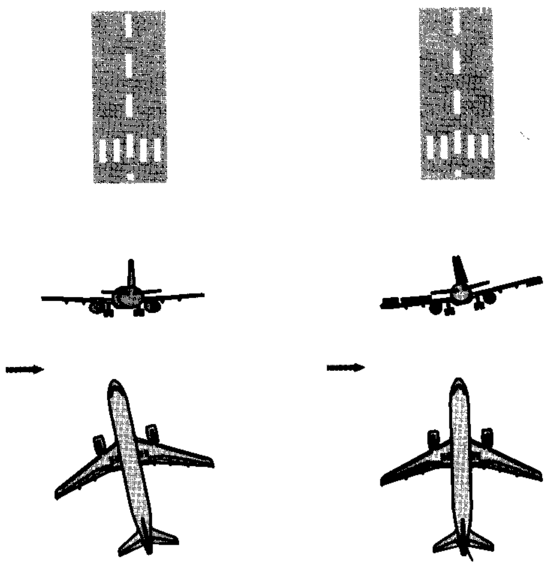
And altitude loss until reducing the sink rate changes by the aircraft weight even with the same flare operation (Table 2).

Wt [klb]	Alt Loss [ft] Flare to PCH up	Alt Loss [ft] Flare to Stop Sink
240	10	20
280	20	45

Table 2 Altitude Loss during Flare

3.5 Landing in Cross Wind Condition

In cross wind condition, the pilot takes the crab angle that is the angle between the aircraft axis and the traveling direction, equal to the cross wind component and makes approach. There are three method, the landing with crab angle, the landing that the aircraft axis coincides with the runway centerline (Wing Low) and the landing combined both.



Crab Landing　　Wing Low Landing

Fig. 3 Landing Method

When with wing low landing the wind is even, if the appropriate rudder with corresponding bank is taken, the aircraft stabilizes in the state, but when the gale and gust exist, it is difficult to control the aircraft in stable state because the required rudder and bank quantity changes.
As for crab landing, big yawing moment occurs at touch down and it is not desirable from viewpoint of comfort in case that runway surface is dry.
For example of B767, WCA of the 10.5 degrees with crab landing and bank angle of 5 degrees with wing low landing is required under the condition, airspeed of 140kt and cross wind of 25kt.
In our B767 operation, the wing low landing is taken below approximately 15kt cross wind and above that the method of combining wing low and crab landing is taken. For instance, the pilot steppes on the rudder of the leeward and turns the control wheel to direct the aircraft axis to the runway centerline direction then adjusts the aircraft track to the runway centerline. After touch down, the axis is adjusted to the runway direction slowly until the nose gear grounds. This method is effective because it is easy to control the aircraft when the aircraft energy is lost suddenly encountered wind shear. The sufficient training is required in order to control the aileron and rudder appropriately.

3.6 Effect of Runway Slope

The runway normally has up or down slope. When the flare is made with only visual information, there are cases that the pilot misunderstands the pitch up amount from relative relationship with the runway surface. It is necessary to pay attention to the runway that large slope exists.

3.7 Analysis of Landing Technique using Neural Network Method

It is difficult to analyze the process that pilot control the aircraft after recognizing the environmental conditions, therefore, instructor pilot make an advise with sensuous expression in new pilot training. We compared the landing technique of unexperienced pilot with that of experienced pilot by the analysis using Neural Network method. Then, we could obtain the result that the experienced pilot increase the sensitivity for the change of pitch after flare, but unexperienced pilot decrease the sensitivity after flare. This analysis agrees with the pilot comments after this test and it shows this tool is effective to grasp the pilot operation objectively. The detail result of this analysis using Neural Network Method refers to the other paper [1]

4. Landing Technique Corresponding to Environmental Factors

This section is the study when the operational circumstance is severe such as sudden change of the wind, low visibility and contaminated runway etc. In those circumstances, there are many cases that missed approach is the best way rather than landing for the safety.

4.1 Avoidance of Tail Contact

The unexpected decrease of head wind or increase of tail wind brings the decrease of aircraft energy. If it tries to stop the sink rate in this state with only the pitch up, the aircraft touches down with high pitch angle. In addition, when the speed brake is up remaining the control force to control column after touch down, the pitch attitude increased approximately 2 degrees at maximum in 1.5 seconds. At this situation, the risk of tail contact is high. It is important to control the pitch attitude taking into account the wind change and recognizing the allowable pitch attitude at touchdown. In addition, the appropriate callout for pitch attitude is effective.

4.2 Landing on Slippery Runway

In case that the road surface is slippery under the cross wind, the directional control is difficult at rollout because the frictional force of the gear is small. Although the allowable cross wind is changed according to the runway condition, the directional control after the touch down is difficult when the aircraft track differs from the runway centerline just before touch down. As a result of analysis using simulator on slippery runway with cross wind, when the aircraft track has faced to the leeward at touch down, keeping the runway centerline is rather difficult and some cases reached to the off runway.

When the environment and the external factors are worse, the stabilized approach especially becomes important. The pilot recognizes the situation that he is placed, analyses the circumstance expected from the situation from his knowledge and experience and takes the best action. That is required to the pilot.

5. Conclusion

We investigated the landing technique during visual approach and studied the avoidance of its risk. Attendant upon the technological innovation, it is presumed that in the distant future, automation takes the place of pilot duties, but it seems to be the key point how it keeps taking in the part where the pilot controls based on the estimate from the past experience to the system.

Under the present circumstances, most of flight lands with manual operation, this circumstance is expected to continue for some time. The landing techniques of the pilots slightly differ depending upon the pilot individuals. The contents that are reported here are portion of the verification result, but those are expected to be effective to the young pilot as a guideline to do the stabilized approach and landing. Our group made CD-ROM that summarized this study, has used as the training tool.

References

[1] Suzuki, S., Sanematsu, Takahara, H., *"Analysis of Human Pilot Maneuver Using Neural Network Modeling"*, 24th ICAS2004