Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Research and Analysis – AR-2010-055

Avoidable Accidents No. 3

Managing partial power loss after takeoff in single-engine aircraft

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Research and Analysis - AR-2010-055

Avoidable Accidents No. 3

Managing partial power loss after takeoff in single-engine aircraft

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory Agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in:

- independent investigation of transport accidents and other safety occurrences;
- safety data recording, analysis and research; and
- fostering safety awareness, knowledge and action.

The ATSB does not investigate for the purpose of apportioning blame or to provide a means for determining liability.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements.

When the ATSB issues a safety recommendation, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

Postal address:	PO Box 967, Civic Square ACT 2608
Office location:	62 Northbourne Ave, Canberra, Australian Capital Territory
Telephone:	1800 020 616; from overseas + 61 2 6257 4150
	Accident and incident notification: 1800 011 034 (24 hours)
Facsimile:	02 6247 3117; from overseas + 61 2 6247 3117
E-mail:	atsbinfo@atsb.gov.au
Internet:	www.atsb.gov.au

May11/ATSB39
ISBN: 978-1-74251-166-5

Introduction

This ATSB booklet aims to increase awareness among flying instructors and pilots of the issues relating to partial power loss after takeoff in single-engine aircraft. Accident investigations have shown that a significant number of occurrences result in fatalities or serious injury due to the aircraft stalling and subsequent loss of control resulting in a collision with the ground or water.

Historically, the simulated total loss of power and subsequent practice forced landing has been the core of a pilot's emergency training. The data, however, shows that during and after takeoff, a partial power loss is three times more likely in today's light single-engine aircraft[1] than a complete engine failure. Furthermore, there have been nine fatal accidents from 2000 to 2010 as a result of a response to a partial power loss compared with no fatal accidents where the engine failed completely.

While one reason for the disparity in these statistics could be explained by the more challenging nature of partial power loss, due to the choices confronting a pilot and the decisions that have to be made immediately, it does not fully explain the different outcomes. Another possible factor is training. Total engine failure after take-off is part of the Day VFR syllabus and is taught and practiced throughout a pilot's initial training. However, partial power loss after takeoff is not a specific syllabus item, and probably does not receive the same emphasis during training.

While acknowledging the difficulty of attempting to train pilots for a partial power loss event which has an almost infinite variability of residual power and reliability, analysis of the occurrences supports the need to raise greater awareness of the hazards associated with partial power loss and to better train pilots for this eventuality.

Key messages

Most fatal and serious injury accidents resulting from partial power loss after takeoff are avoidable. This report will show that you can prevent or significantly minimise the risk of bodily harm following a partial or complete engine power loss after takeoff by using the strategies below:

- pre-flight decision making and planning for emergencies and abnormal situations for the particular aerodrome
- conducting a thorough pre-flight and engine ground run to reduce the risk of a partial power loss occurring
- taking positive action and maintaining aircraft control either when turning back to the aerodrome or conducting a forced landing until on the ground, while being aware of flare energy and aircraft stall speeds.

1 Research and data confined to reciprocating engine powered aircraft and may not be appropriate to turbine-powered single-engine aircraft.

Caution: Partial power loss occurrences have a very broad range of characteristics by nature. The most effective risk control method for managing these occurrences may be significantly different between pilots of varying experience and training, aircraft models and the environmental conditions.

Case studies and considerations presented in this report need to be considered in conjunction with individual experience, aircraft type and aerodromes, and are not necessarily appropriate in all situations. In addition, this report is intended to supplement any manufacturer's handling advice that may exist for these scenarios and these are to be given precedence where any conflict exists.

Partial engine power loss during and after takeoff

A partial engine power loss is where the engine is providing less power than that commanded by the pilot, but more power than idle thrust. A partial engine power loss after takeoff event is one that occurs after the aircraft is airborne and on initial climb immediately after takeoff, generally below circuit height, while being within close proximity to the departure aerodrome. For the purposes of this report, a total engine failure preceded by a partial power loss is treated as a partial power loss occurrence, in circumstances where the pilot had taken action in response to the initial reduced power state.

Examples of the causes of engine power loss include, but are not limited to:

- mechanical discontinuities within the engine
- restricted fuel or air flow or limited combustion in the engine, often due to fuel starvation, exhaustion or spark plug fouling
- mechanical blockage in the engine setting controls, such as a stuck or severed throttle cable.

From 1 January 2000 to 31 December 2010, there were 242 occurrences (nine of which were fatal) reported to the Australian Transport Safety Bureau (ATSB) involving single-engine aircraft sustaining a partial engine power loss after takeoff and 75 occurrences (none of which were fatal) reported as sustaining an engine failure after takeoff.

Partial engine power loss is more complex and more frequent than a complete engine power loss

A partial engine power loss presents a more complex scenario to the pilot than a complete engine power loss. Pilots have been trained to deal with a complete power loss scenario with a set of basic checks and procedures before first solo flight. Furthermore, this training, which emphasises the limited time available to respond, is continually drilled in an attempt to make it second nature. However, pilots are not generally trained to deal with a partially failed engine. Following a complete engine failure a forced landing is inevitable, whereas in a partial power loss, pilots are faced with making a difficult decision to continue flight or to conduct an immediate forced landing.

The course of action chosen following such a partial power loss after takeoff can be strongly influenced by the fact that the engine is still providing some power, but this power may be unreliable. As the pilot, you may also have a strong desire to return the aircraft to the runway to avoid aircraft damage associated with a forced landing on an unprepared surface. The complexity of decision making in such circumstances is further compounded by the general lack of discussion and training on this issue. In dealing with this, you will need to rely on your knowledge and experience.

As occurrences of partial engine power loss occur three times more often than a total power loss, your pre-flight planning should consider a partial engine power loss scenario as much as a complete power loss scenario.

Report contents

By extending already established procedures dealing with total power loss to a partial engine power loss scenario, this report will present the different options to consider during your pre-flight planning.

The remainder of this report is presented in the same sequence of events as if conducting a flight, in order to help you take partial engine power loss avoidance or management into account during each of these stages. The sequence of events is divided into:

- pre-flight planning (which focuses on preparing for loss of power)
- avoiding a partial power loss after takeoff
  - operations on the ground (preventing loss of power)
  - the pre-takeoff self briefing
  - on takeoff checks and rejecting the takeoff.
- managing a partial power loss after takeoff (planning considerations and maintaining control)
  - forced or precautionary landing (on or beyond the air field)
  - turning back towards the departure aerodrome.

Pre-flight planning and self briefing

Pre-flight planning

In a partial engine power loss after takeoff, the pilot needs to make a decision on how to manage the situation under conditions of stress, uncertainty, high workload, and time pressure. By considering factors such as wind direction and landing options on and off the airfield, and in front of and behind the aircraft during your pre-flight planning, you will reduce your mental workload if a partial engine power loss occurs. Having made a plan may also mitigate some effects of decision making under stress, such as reduced short term memory. In addition, knowing that you have planned your action under non-stressful and controlled circumstances should give you the confidence to carry out the actions in an emergency situation.

Thus, you are encouraged to take the possibility of a partial engine power loss into account and plan for action as part of your threat and error management strategy.

Your pre-flight plan should take into account:

- the runway direction and the best direction of any turn
- the local wind strength and direction on a particular day
- terrain and obstacles
- decision points (taking into account aircraft height and performance) where different landing options will be taken, such as:
  - landing on the remaining runway or aerodrome
  - landing outside the aerodrome
  - conducting a turn back towards the aerodrome.

Pre-flight self briefing

All single-engine aircraft pilots, just like multi-engine aircraft pilots, should self brief prior to each and every takeoff. The self brief is important as it serves as a reminder of your planned actions in the event of an emergency such as a partial power loss. The following section further describes the role of the pre-flight self brief.

Avoiding a partial engine power loss

Pre-flight checks

There were a number of occurrences reported by the ATSB where there was evidence of either detection of an existing engine system abnormality, or a likelihood that a problem could have been detected and prevented before takeoff. Prevention is better than a cure, and pre-flight checks are a vital barrier in reducing the likelihood of a partial engine power loss after takeoff actually occurring.

Aircraft pre-flight – physical inspection

Some occurrences involving fuel starvation, exhaustion or contamination which resulted in a partial power loss, often followed by a complete engine failure, may have been preventable at the physical inspection stage before flight. Going though all relevant physical checks is a good way to reduce the risk of a partial or complete engine power loss occurring. Even if the aircraft maintenance release is already signed out for the day, it is essential to conduct a thorough pre-flight before every flight. This includes engine and fuel system components.

Fuel related partial power loss

The appropriate selection of fuel tank before takeoff, and ensuring that fuel drains are not left open or leaking, and fuel caps are on and closed correctly are factors that could have allowed the detection or prevention of fuel related partial power loss occurrences . Fuel related partial power loss events are associated with engine surging, a particularly unpredictable form of partial power loss, which often leads to complete engine failure.

Be mindful of the particular fuel system fitted to the aircraft and the relevant engine manufacturer’s requirements. There have been a number of partial power loss events where it was probable that a partially selected fuel tank or inappropriate selection led to a fuel starvation event. This is particularly applicable to aircraft with more than two fuel tanks.

Case Study – fuel starvation

The solo student pilot flying a Cessna 172 had just taken off from Jandakot when at 500 ft the engine surged and subsequently failed. The student carried out a forced landing onto a nearby railway access road, and was not injured…The operator advised that the engine failed due to fuel starvation as a result of incorrect fuel selector manipulation, aided by poor fuel selector design.

A review of fuel-related occurrences reported to the ATSB suggests that the following checks may prevent a partial power loss:

- drain fuel from all fuel drain points for water or other contamination
- ensure all fuel drain points are not leaking (especially bayonet style fittings that can be locked open)
- give conscious thought to the fuel tank required for takeoff (header tank or fullest tank)
- ensure that there is sufficient fuel tank quantity and that you are familiar with the correct method of checking fuel tank capacity, for example crosschecking fuel gauge and the tank dip and not relying on a single source of information for the fuel reading.

Manage distractions

Although the above are done regularly by most pilots and are generally intuitive, it is possible that distractions or time pressures mean that they may not be performed thoroughly. It is recommended that threat and error management considerations, in other words planning for distractions and other pressures, be given to this phase of flight by all pilots. For example, minimise distractions by telling passengers that you can't be interrupted at this point in time, or if distracted, go back as many steps as is necessary to ensure that all relevant checks are completed.

Almost one quarter of engine power loss occurrences have occurred while the pilot was conducting a 'touch-and-go' when performing circuit practice. There were several partial power loss occurrences in the circuit which were reported as being caused by fuel starvation or exhaustion, some of which were fatal. Some methods to avoid these fuel related problems are through having a fuel management plan, even on short flights, and being aware that there may be significantly more fuel burned when the fuel/air mixture is not leaned for optimum performance. A thorough understanding of the aircraft's fuel system is also important, such as knowing how to confirm fuel quantity.

Minimise aircraft fuel configuration changes

There are a number of cases where it is probable that residual, clean fuel in the fuel lines sustained the engine for the take-off run, however, was insufficient for sustained flight, with fuel starvation occurring soon after rotation (for example due to a fuel tank selector being incorrectly manipulated or contaminated fuel). Thorough engine run-up checks can help to diagnose any abnormalities with both the engine and the fuel system and help to prevent these types of occurrences.

Run-up on the system intended for takeoff

It is important that the entire engine and fuel system is unchanged (with the exception of take-off items like fuel pumps being off for run-ups to test worst case conditions) between engine run-ups and takeoff to prevent introducing any additional hazards into the initial phase of flight.

For example, use the same fuel tank for engine run-ups as that used for takeoff. This helps to minimise the risk of encountering fuel related engine problems after takeoff.

Engine run up checks – Adhere to the performance thresholds

A number of partial power loss occurrences had engine abnormalities which were identified by the pilot during high RPM engine run-ups prior to takeoff. Checking for an RPM 'drop and hold' after carburettor heat application and checking and comparing individual magnetos for a specified RPM drop range are simple but important steps in preventing a partial engine power loss. Moreover, engine oil temperatures and pressure gauges should be within accepted aircraft operating limitations. In addition, there have been a number of occurrences where the engine was misfiring or generally running rough prior to takeoff, with a subsequent partial loss of power occurring shortly after takeoff.

Some examples of partial engine power loss events reported to the ATSB where the engine condition could be detected in most situations by an RPM change below the normal threshold during engine run-ups were:

- fouled spark plugs (at least 19 cases)
- carburettor icing (at least 11 suspected cases) and other carburettor problems (at least 11 cases).

Case Study – fouled spark plugs

It was apparent on rotation from the Mount Vale airstrip that the Tobago was not developing full climb-out power and the nose was lowered to maintain flying speed. Due to the terrain (in a valley, surrounded by hills) and after initial checks (mags, fuel and mixture), a decision was made to conduct a precautionary landing in a paddock. During the landing roll the aircraft crossed a fence – denting both wings and dislodging one wheel fairing However, none of the four occupants were injured. Run-ups confirmed the aircraft was not developing full power due to the failure of two spark plugs in separate cylinders. After running the engine for 10 minutes the spark plugs cleared. Although the magneto check showed the engine running smoothly, the RPM drop was larger than normal. From discussions with pilots familiar with the area, it appears that there was a degree of downdraft – exacerbating the reduced climb performance at less than full power.

There were also a number of cases where general rough running was reported; however, the causes of the malfunction were not confirmed.

Case Study – carburettor icing

After departure from Murray Bridge aircraft landing area, the Jabiru engine began running roughly. The pilot applied carburettor heat and the engine performance improved. On downwind, the rough running returned. The pilot conducted a glide approach and landed.

The take-off brief

The self take-off brief (discussed earlier) is generally conducted once all engine run-ups are complete, just prior to taxiing to the holding point for takeoff. This serves as a reminder of your original plan (discussed in *Pre-flight planning* above, and also in pilot actions below), and refines your plan to a specific route given the specific wind conditions and runway direction. The self brief also helps in responding in an abnormal or emergency situation. Generally speaking, if you self-brief your plan of action just before flight, you have more chance of 'staying ahead' of the aircraft and being able to concentrate on flying.

Incorporating partial engine power loss with complete failure considerations

If a partial power loss results in aircraft performance that is degraded to the extent that height cannot be maintained, a partial power loss can be treated as a complete engine failure with a potentially extended glide distance.

The pre-takeoff brief should take into account the wind speed and direction and the aerodrome surroundings when considering forced landing options, and should include consideration of a complete engine failure. If considering turning back toward the aerodrome, such as has been the case with many reported partial engine failures (predominantly where height could be gained or at least maintained, or where sufficient height was available), forced landing options along the flight path should be considered, while keeping in mind that if any wind is present, the groundspeed will be increased when on downwind.

The take-off run

An engine power abnormality may not be detected until engine run-ups or the application of full power on takeoff. The initial static RPM at full power checks are a vital barrier in avoiding a partial engine power loss after takeoff. In addition, the aircraft acceleration should be monitored along the runway to ensure it is as expected.[2]

In some occurrences reported to the ATSB, partial engine power loss symptoms were present before rotation on the take-off run. The symptoms ranged from those that on reflection seem obvious, such as misfiring, to a static RPM reading less than the recommended minimum level, or sluggish acceleration. Pilots reported that they had noticed symptoms of an abnormally performing engine, but had continued with the takeoff as they were not sure of the requirements and/or did not consider that an engine failure or partial engine power loss would occur.

Incorrectly set power controls, such as the propeller not set to full fine, the mixture not set to full rich[3], or carburettor heat not selected to off, as a result of missed or forgotten checks, can also lead to a partial loss of power.

Use the entire runway for takeoff

Using the full runway length instead of making an intersection departure allows a greater possibility of landing on the remaining runway or field if an engine failure or power loss occurs.

2 Some instances of sluggish acceleration may be caused by reduced engine power available due to low air density, the aircraft being relatively heavier than usual or an up-gradient takeoff. However a rejected takeoff may still be a good option in the above cases.

3 Mixture set to full rich or set to the richest level before rough running occurs when the local air density is low.

Rejected takeoffs

Many of the partial engine power loss events detected during the take-off roll resulted in the pilot abandoning the takeoff. Rejected takeoffs reported to the ATSB occurred at varied positions along the runway, ranging from immediately after full power application to the point of rotation for takeoff, with approximately one third being at rotation speed or at least half-way along the runway. Approximately one quarter of all rejected takeoffs after a partial power loss occurred after touch and go landings during circuit training.

The most common reasons provided by pilots for rejecting a takeoff were a rough running engine, reduced power, having a low static RPM, or poor aircraft acceleration.

Of the 24 rejected takeoffs following partial power loss between 2000 and 2010, 20 resulted in no injuries and four resulted in minor injuries. Damage to the aircraft was confined mainly to the wings, propellers, wheels and tail section of the aircraft.

Approximately one quarter of the rejected take-off occurrences resulted in either a runway overrun or a ground loop to avoid an overrun.

Case Study – low RPM on takeoff

The pilot of the Grob was cleared for departure from Parafield after normal run-up and pre-takeoff checks. As the throttle was advanced to full, a subsequent check showed the static RPM was approximately 2200 with all other indications normal. As this was below the minimum static RPM of 2350 as per the aircraft flight manual, the takeoff was rejected and the aircraft vacated the runway safely via taxiway Juliet Two.

Reports to the ATSB indicate that all rejected takeoffs[4], even near take-off speed, did not result in serious injuries. Thus, you should be alert to detect any partial engine power loss early in the take off run, as an immediate response to sluggish acceleration or reduced power during takeoff will most likely minimise the chances or severity of personal injury.

4 Occurrences involving single-engine aircraft suffering a partial or complete power loss on the ground.

Don't push on

Many engine abnormalities can be detected early and fixed with minimal disruption to the flight. However, a pilot may feel the pressure to continue with the flight without fixing the problem.

'Push-on-itis' at takeoff is similar to that related to continued flight in adverse weather. Similar factors such as commercial pressures, last light restrictions, and advancing weather may exist when proceeding with a takeoff with a known engine abnormality or compromised engine performance. Pilots may be so focused on getting the aircraft airborne that they are less likely to be prepared to act quickly if an unexpected emergency occurs.

The message is simple: if you don't know, don't go. It is better to be on the ground and frustrated about a faulty aircraft than in the air wanting to be safely on the ground.

Case study – pushing on

Witnesses reported that after start and during taxi, the Beech C24R engine sounded as if it was `running roughly' and `missing'. During the take-off roll, on the 1,000 m dry gravel airstrip from the NSW property, the aircraft appeared to accelerate slowly, with witnesses reporting `frequent missing' and `backfires'... Several seconds later the engine noise ceased followed by the sound of impact. All three occupants received fatal injuries. Prior to impact, the aircraft had struck the tops of several 8 m tall trees that were 108 m beyond the end of the airstrip...The aircraft had incorrect heat range spark plugs fitted in the top positions in all of the engine cylinders. The aircraft and engine manufacturers indicated that the use of these spark plugs can result in detonation and pre-ignition.

ATSB investigation 200102289

Managing a partial engine power loss after takeoff

Partial engine power loss can range from providing very little power to almost full power, with varying levels of reliability of the remaining engine power. When faced with a partial power loss, pilots should not try to diagnose the engine problems at the expense of maintaining aircraft control.

Maximise your height or minimise your distance

Climbing out at the manufacturer's recommended 'best rate' or 'best angle' speeds, depending on your aircraft and location, will maximise your options if a partial power loss or engine failure occurs. Adopting a 'cruise' climb setting before the aircraft has reached a safe altitude may place the aircraft beyond the possibility of a glide return, even if above the 'turn-back' height of your aircraft.

The following initial actions should be considered when responding to a partial loss in power:

- lower the nose to maintain the glide speed of the aircraft
- conduct the basic initial engine trouble checks as per an engine failure[5] in accordance with manufacturer's advice. However, this should be done only if there is sufficient time
- maintain glide speed and assess whether the aircraft is maintaining, gaining or losing height to gauge current aircraft performance. This will help to inform the options available for landing

5 Basic initial engine trouble checks often include checking carburettor heat on, mixture full rich, magnetos on both, fuel pump on, tank selection, primer secure.

- fly the aircraft to make a landing, given the aircraft's height and performance, and the pre-planned routes for the scenario. If turning is conducted, keep in mind an increased bank angle will increase the stall speed of the aircraft. Keeping the aircraft in balance will minimise rate of descent in any turn
  - having a minimum planned turning height is recommended; CASA suggests a minimum height of 200 feet above ground level (AGL) for rolling wings level (refer below). Below your planned height, a straight climb until above the minimum turning height or descent to land would be the only option
- re-assess landing options throughout any manoeuvres. Be decisive but be prepared to modify the plan if required
- land the aircraft -
  - have a minimum height planned to roll wings level. It is suggested in CASA documentation that turns should not be attempted below 200 feet AGL[6]. However, this will depend on the aircraft's roll rate, the present airspeed and personal experience
  - maintain glide speed up to the point of flare; this will ensure that when flaring there is enough energy to arrest the vertical descent rate.

As is the case with a total power loss after takeoff, during a partial power loss after takeoff, diagnoses of the cause of the engine problem should not be attempted at the expense of maintaining control of the aircraft.

Case study – know your fuel system: if you don't know – don't go

After the initial takeoff from Moorabbin, the engine of the PA-24 failed to develop full power and the pilot conducted a low-level circuit and landing. Following ground runs, a second takeoff was made, but during the initial climb the engine stopped and the pilot carried out a wheels-up landing. The pilot reported that the fuel was lower than was determined by visual and gauge indication.

A review of the data shows that there are generally three decisions you can make when faced with a partial power loss after takeoff:

- forced and precautionary landings immediately after takeoff within the aerodrome
- forced and precautionary landings immediately after takeoff outside the aerodrome
- turn back towards the aerodrome to land:
  - with a re-assessment resulting in a forced landing outside the aerodrome
  - with a forced landing conducted on the aerodrome.

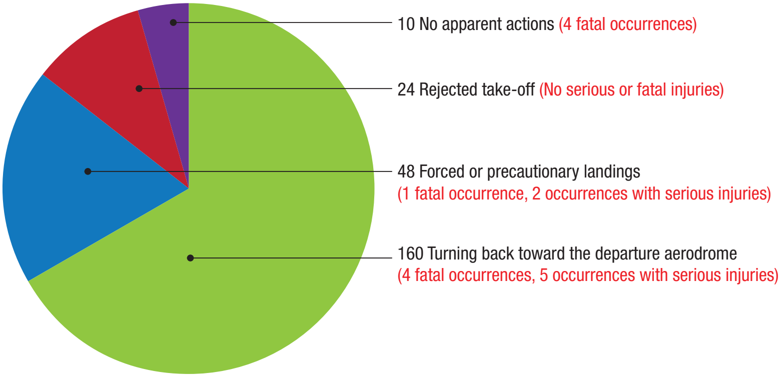
6 Civil Aviation Safety Authority, (2006) *Flight Instructor Manual Aeroplane*, Issue 2, p 39.

Figure 1 shows the initial actions taken by pilots in the 242 partial power loss occurrences between 2000 and 2010. It shows that pilots turned back towards the aerodrome in two-thirds of the occurrences. Of these 160 occurrences, 145 resulted in the aircraft making it back to within the grounds of the departure aerodrome.

In 19 per cent of occurrences, a forced or precautionary landing was conducted, although 22 out of the 48 occurrences landed within the grounds of the aerodrome immediately after takeoff. In 10 per cent of occurrences, the pilot rejected the takeoff before lifting off the ground.

In 10 occurrences, the pilot did not appear to have taken any specific initial action, resulting in a collision with terrain, seven of which involved some form of loss of control.

Figure 1: Initial actions taken by pilots after a partial power loss

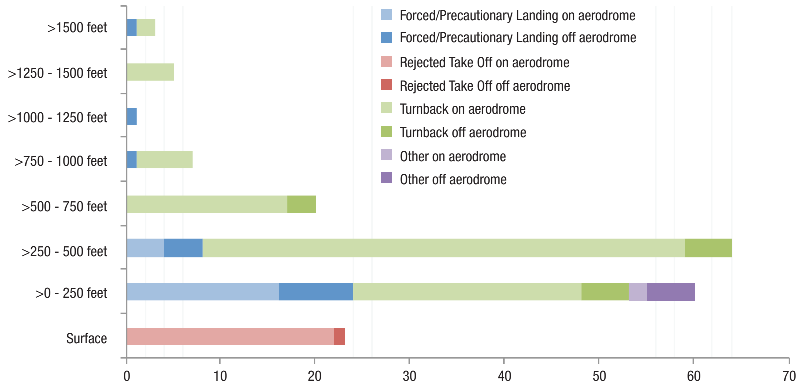


Maintain glide speed

ATSB occurrence reports show that the initial actions taken by the pilot do not necessarily affect the final outcome; what is more important is that the primary focus be on maintaining airspeed to prevent stalling and also allow energy for flare, rather than diagnosing problems. Thought should be firmly on where the aircraft is going, maintaining control and situational awareness, and dealing with the situation at hand.

The height range for all partial engine power loss occurrences (where the height of failure was reported) are shown in Figure 2 below. Figure 2 shows the number of forced landings was relatively higher between the surface and 250 ft than above this height, where turning back to the aerodrome was the dominant decision. However, it is probable that many of the forced landings involved aircraft where this would have been the only option, due to the aircraft being unable to maintain height, and not having enough height to manoeuvre.

Figure 2: Altitude of partial engine power loss (where known), actions taken and general landing position



No pilot response/ action after a partial power loss

Of the 10 occurrences where there was no clear action taken by the pilot, four resulted in fatalities. These fatal occurrences were often characterised by the aircraft tracking straight ahead after takeoff, slowing to maintain height, and then a loss of control through a stall and / or spin at an unrecoverable height, or colliding with objects such as trees.

Make decisions pre-flight

Deciding on responses to a partial engine power loss before the flight will reduce your workload during the event and assist you in taking some form of considered action. Taking some form of such action will greatly reduce the risk of injury.

Set expectations

Being clear with yourself and setting clear expectations with your passengers about your intended plan of action can help with carrying out your plans and reduce the chances of distractions during important pre-flight preparations.

A small percentage of cases (8 out of 232 occurrences) where the pilot initially took decisive action eventuated in a loss of control. However, where no clear decision and subsequent action was taken by the pilot, some form of loss of aircraft control eventuated 70 per cent (7 of out 10 occurrences) of the time. In those occurrences where there was no clear action taken by the pilots to land their aircraft, the pilot typically continued flying until either a collision with an object or contact with the ground occurred, either through a gradual descent or following a stall and / or a spin as a result of trying to maintain height.

Case study – no apparent action taken

The Cessna U206 took off from the airfield in Queensland with the pilot and six passengers onboard. At approximately 100 feet, the aircraft performed as if the power had been 'pulled back'. The aircraft continued in a straight line descending slowly before impacting a tree just over 1 kilometre from the airstrip and crashing into a dam. Just prior to impact, it was reported that the stall warning horn had activated. A flat field underneath the aircraft's flight path was an option for landing for the entire distance travelled.

ATSB investigation 200600001

The typical height above the airfield when the partial power loss first occurred for occurrences where no apparent action was taken was between 50 and 100 feet.

Forced and precautionary landings within the aerodrome immediately after takeoff

There were 22 partial engine power loss occurrences after takeoff where a forced landing was conducted within the aerodrome boundary by landing either straight ahead or slightly off the runway heading. These occurrences were from a typical height of 25 feet, although some were above 150 feet [7]. There were five occurrences where the aircraft was either at circuit altitude or beyond the perimeter fence, but was able to land on another runway.

Of the 27 forced and precautionary landings within the aerodrome, two resulted in serious injury and three resulted in minor injuries. There were no fatal injuries. The case study below describes one of the accidents that resulted in serious injury.

In most of these immediate forced landings, the pilot landed the aircraft on the remaining runway, half of which involved an overrun. Many of the runway overruns resulted in collisions with objects such as fences, shrubs and drainage ditches. However, most collisions with objects did not result in serious injury.

Terrain features such as unfavourable overrun areas should be considered during planning. However, in many cases these terrain features cannot be avoided in the event of an emergency landing or overrun. With the exception of large drainage ditches running perpendicular to the direction of flight (which can cause rapid deceleration), you can use many of these features to decelerate the aircraft without undue risk of injury.

7 The height from which an on aerodrome landing is possible is dependent, among other things, on aircraft type, runway length, aerodrome size and wind.

Case Study – turning at very low height resulting in a wing tip strike

The engine of the F-206 lost power shortly after the pilot had retracted the landing gear during the initial climb from Bankstown. The pilot entered a glide with the intention of landing straight ahead on runway 29C. At about 75 feet AGL, the pilot partially closed the throttle and the engine briefly regained power. This caused the nose of the aircraft to pitch up and roll to the left. The pilot lowered the nose again, and with very little runway remaining ahead, elected to turn to the right in an attempt to land the aircraft on runway 36. The engine lost power again during the turn. The pilot then elected to roll the aircraft to the left and land straight ahead; however, insufficient time remained to roll the wings completely level. The aircraft impacted the ground with the landing gear retracted in a right wing low attitude just past the intersection of runway 29C and runway 36. During the impact sequence, the aircraft spun through 180 degrees to the left as it slid along runway 29C. The aircraft was substantially damaged and the pilot sustained serious injuries.

Completely pull the power to land on the remaining runway (or aerodrome)

In some cases, power has reportedly fluctuated unpredictably with the movement of the engine throttle. One technique that has been employed by pilots has been to completely pull the throttle once a landing point is assured, rather than partially reducing the throttle.

Conducting the forced/precautionary landing on the aerodrome

The following factors were identified as being influential in reducing the potential for injury following a partial power loss after takeoff when landing immediately on the aerodrome without turning:

- The sooner engine power is cut, the greater is the landing distance available. Unwanted airspeed, aircraft pitching and additional height has been reported to the ATSB as an effect of not cutting the engine throttle completely. This may result from some power being restored and is likely to reduce the landing distance available.
- Turns increase the possibility of stalling and wingtip strikes at low level.
- The immediate deployment of full flaps is recommended if time permits, as this will also help to reduce the aircraft groundspeed prior to ground contact. However, this may result in reduced braking effectiveness on the ground and ‘float’ due to increased lift, especially in low wing aircraft.

Basic actions to take if committed to a landing from a very low height while within the aerodrome confines should follow the trained procedures for an engine failure after takeoff. As the engine may be providing some power, a pilot may be hesitant to cut power completely. However, the decision to land on the aerodrome needs to be acted on rapidly to ensure the landing distance is maximised.

Forced and precautionary landings after takeoff beyond the aerodrome

If a partial power loss is detected once airborne and within the aerodrome confines, there may be some situations where it seems appropriate for flight to be continued beyond the perimeter fence. For example, if there is no over-run area or the over-run area is unsuitable and there are suitable emergency landing areas or fields beyond the aerodrome, continuing flight with partial engine power available may be appropriate. Such situations should be considered in conjunction with engine failure after takeoff training, and should be part of the pre-flight briefing.

Once the aircraft is airborne and beyond the point where a landing straight ahead or slightly off the runway direction within the aerodrome boundary is no longer possible, there are only two main options available to a pilot:

- conducting a forced or precautionary landing on or off the aerodrome once beyond the perimeter fence
- commencing a turn with the intent of landing at the departure aerodrome on the same or another runway (discussed in the next section), or within the aerodrome grounds.

Only 21 occurrences involved the pilot conducting a forced or precautionary landing after takeoff once beyond the aerodrome boundary. There was one fatal accident and three accidents where minor injuries were incurred. The fatal accident involved a successful ditching into a body of water, resulting in minimal damage to the aircraft; however, one of the passengers drowned after leaving the aircraft.

For off aerodrome landings, the typical height from which pilots conducted forced or precautionary landings after detecting a partial power loss was 200 feet AGL.

Case study – maintaining control

The PA-32 aircraft took off from Brampton Island aerodrome with the pilot and four passengers on board. Upon passing 400 ft after takeoff, the pilot described that the aircraft's engine suffered a significant reduction in power and began to vibrate, although the engine did not cut out straight away. The aircraft was gently banked toward the east to be close to the shore; a turn back was ruled out as an option. The pilot landed the aircraft on the water along the line of the chop. In the resulting collision with the water, the pilot's head impacted the instrument glare-shield. One passenger suffered fractures to fingers, and the pilot sustained soft tissue damage to one eye, however the remaining passengers were uninjured.

ATSB investigation AO-2008-022

Conducting the landing off the aerodrome

Incident reports received by the ATSB indicated that pilots sometimes use residual power to set up an approach; however, you should plan as if an engine failure is imminent.

Again, in a partial engine power loss event, the engine may not be relied on to continue to provide any level of power. Therefore, it may be advantageous to conduct a forced or precautionary landing as if experiencing a total engine failure, as it removes the variability and unknown reliability of some engine power, particularly where there are suitable landing options available. Moreover, all pilots are specifically assessed and trained to deal with a complete engine failure after takeoff.

Use the aircraft structure and your surroundings to minimise injury

In the event of a forced landing away from the aerodrome, a pilot faced with an unsuitable area in which to stop should attempt to slow the aircraft as much as possible. Protecting the occupants from injury should be your highest priority, rather than preventing damage to the aircraft.

Considering the landing gear or using the aircraft structure, such as the wings, to absorb energy on impact with obstacles, are methods that have been employed to decelerate an aircraft in these circumstances. Avoiding direct contact of the fuselage with solid objects reduces the risk of serious injury.

Turning back toward the aerodrome following a partial power loss

With the encroachment of urban development on many airports and the fact that many of their runways do not have favourable terrain beyond them to land on after takeoff, another option may be to conduct a carefully planned turn while considering options for a forced landing.

If, following a partial loss of power, sufficient power[8] is available to maintain altitude, there may be a possibility of safely landing at an aerodrome, provided that the aircraft can be positioned for an off-airfield landing anywhere along the flight path. Invariably, there are many scenarios where it might be considered inappropriate to conduct a turnback. For example, consideration should be given to additional hazards such as other aircraft, obstacles, an unfavourable wind component, increased stall risk during a low-level turn and surrounding terrain.

8 Generally, enough power to maintain altitude, however, if the aircraft has sufficient height the aircraft may be able to return, even in a glide. A glide return is aircraft type specific, and must be considered and planned for according to the aircraft performance specifications.

Case study – surging power followed by loss of control

The pilot of a PA-32 aircraft reported taxiing for departure from runway 14 at Hamilton Island, Queensland. On board the aircraft were the pilot and five passengers. Shortly after the aircraft became airborne, the engine was heard 'coughing' and 'misfiring', before 'cutting out' and then 'starting again'. The aircraft was seen to commence a right turn, and the engine was again heard 'spluttering' and 'misfiring'. A number of witnesses reported that, when part way around the turn, the engine again 'cut out', and the aircraft descended and impacted the ground. The six occupants of the aircraft were fatally injured...Based on witness reports, the investigation concluded that the pilot initiated a steepening right turn, and the aircraft stalled at a height from which the pilot was unable to affect recovery.

ATSB investigation 200204328

Planning for the turn back following a partial power loss

It is important to note that part of a good turn back management plan is to consider and prepare for a landing off the aerodrome until the turn is completed and the aircraft is positioned for a forced landing on the aerodrome. A good turn back management plan should not allow the aircraft to be placed in a more hazardous state than if a forced landing were to be conducted once beyond the aerodrome boundary. Furthermore, the characteristics and criterion for a turnback are aircraft type specific, and should be taken into account when planning.

The four main considerations when assessing if a turnback is possible are:

- height available
- remaining engine power available – do you have enough power to climb
- increased stall speed associated with any increase in angle of bank increasing the risk of an aerodynamic stall
- level of confidence in the remaining engine power – but assume the engine may fail at any moment.

Consider whether there is enough energy to maintain height or sufficient energy for return; however, assume that a complete engine failure is imminent, and be prepared for a forced landing.

During a partial power loss, engine power may be unreliable, thus affecting whether a turn back and safe landing on the aerodrome is possible. However, engine problems should not be diagnosed at the expense of maintaining control of the aircraft. Instead, maintaining airspeed and looking for landing options off the aerodrome are more crucial and will mitigate the hazards of engine instability and reduced power.

Considerations for a *plan of action* for turning back to an aerodrome should include the following:

- Is the terrain that the aircraft will be flying over better or worse than landing straight ahead and what will be the groundspeed on landing at any point around the turn (consider in planning, although be mindful that the helical path[9] will change depending on the wind velocity and where the partial power loss occurs). Keep in mind that the ground speed will increase by twice the headwind component when turning downwind.
- Maintain the glide speed of the aircraft. Do not attempt to maintain height by reducing airspeed. In a turn, there is a greater risk of stalling (in particular if the engine is surging) where airspeed has been sacrificed for height. The

9 A circular ascending or descending flight path at constant rate of climb or descent.

glide speed of the aircraft will provide a safety buffer from the stall in a turn with a moderate bank angle, allow manoeuvrability, and provide sufficient energy for flare. This glide speed should be maintained even if the aircraft is descending.

- Have a maximum bank angle planned for the turn[10], keeping in mind that the idea is to optimise angular turn rate per foot of descent. Also keep in mind the increased load factor on the wings. Be aware that below a certain height at a given descent rate, it will not be possible to return to the aerodrome, and that the engine condition can change at any point. Be realistic, and take account of the hazard of turning at very low levels.
- Have a minimum altitude set where the wings are to be rolled level and the aircraft set up for landing. No matter where you are in the turn, do not try to increase bank angle to increase the rate of turn – CASA recommends a minimum wings level height of 200 feet[11], however, individual skill, experience and judgement, and the circumstances of the situation at hand will determine this height.
- Pilots should focus on flying the aircraft and continually assess landing options available in case of a complete engine failure during a turn back. Focus mainly on the arc where you would be able to land if the engine had fully failed - this is the current landing option. CASA[12] recommends that scanning the environment should take 85 per cent of the time available, 10 per cent on checking aircraft attitude including lookout, and 5 per cent of the time scanning of the altitude and airspeed indications.

Case Study – quick action

'After takeoff from runway 15 Lismore and having turned right in accordance with CAOs [Civil Aviation Orders] and Ag ops [agricultural operations] exemptions, I thought I detected an engine surge, possibly fuel related and after turning on the fuel pump the engine ran smoothly but I elected to do an immediate descending turn through about 180 degrees, power assisted, from about 500 feet and landed back on runway 33. The landing and subsequent check of systems revealed no abnormalities other than having in my haste to get going I [sic] had left the fuel tank selector on the fuel tanks with not a lot of fuel in it selected. The fuel system in Fletchers is such that this can occur with fuel levels below 1/4 of a tank. I selected the full tanks and no further problem was experienced. I returned to the runway and departed for Casino to continue with the intended ag work planned for the day.'

10 The optimum bank angle for turn rate per height lost in an unpowered balanced turn is 45 degrees.

11 Civil Aviation Safety Authority (2006) *Flight Instructor Manual Aeroplane*, Issue 2, p 39.

12 Civil Aviation Safety Authority (2006) *Flight Instructor Manual Aeroplane*, Issue 2, p 29.

- If the re-assessment of the situation reveals that the aircraft may not be able to return, given the aircraft sink rate, a forced landing should be considered as pre-planned.

If a turn back is conducted, here are some things to think about *during* the turn.

- Be aware of the bank angle for the best turn rate for height lost, which is 45 degrees; however, be aware that the stall speed is increased by approximately 19 per cent. To maintain the aircraft's glide speed, the nose will need to be lowered due to the increased drag.
- Be aware of the terrain to be covered while in the turn.
- Be prepared at any time to cease turning if the engine performance deteriorates and land straight ahead.

If the engine is surging, it is likely to completely fail and thus needs to be treated with extreme caution. You need to be vigilant about maintaining airspeed.

Other considerations about turn backs following a partial power loss

ATSB occurrence data shows that almost two-thirds of pilots elected to turn back in response to a partial power loss event after takeoff. Of these, 94 per cent involved nil injuries. Nineteen per cent of partial power loss events resulted in a forced or precautionary landing, and of these, 81 per cent resulted in no injuries. The fatality/serious injury rates were similar between the two scenarios. However, it is likely that there were more severe power losses associated with forced landings (which includes forced landings where height could not be maintained, and it may have been physically impossible to conduct a turn-back) on average when compared with turn backs.

Four fatal accidents and one serious injury accident involved loss of control after a turn back due to the aircraft entering an aerodynamic stall and spin, followed by an impact with the ground. A turn back requires accurate flying during a period of high stress to prevent a stall and possibly a spin occurring. If an aerodynamic stall and or spin occur, given that these circumstances are likely to be at low level, there is little likelihood of a successful recovery. With careful management and by being aware of the hazards that can lead to loss of control events, the risk of being involved in a stall/spin accident can be reduced.

Combined with the fact that many aerodromes are surrounded by urban developments, in circumstances where sufficient height or sufficient power make this possible, turning back may be a less hazardous option than a forced or precautionary landing for both people on the ground and in the air.

Case Study: re-assessment of options – turn back with a landing off the aerodrome

The pilot reported that a loud bang came from the engine of the Beech A36 shortly after takeoff from Colac ALA when the aircraft was approximately 450 feet AGL. This was accompanied by a severe engine vibration and a partial loss of engine power. The pilot stated that his initial assessment of the situation was that a low-level circuit could be completed to position the aircraft for a landing on the runway at the aerodrome. When it became apparent that the aircraft was not maintaining altitude, the pilot decided that the safest option would be to land the aircraft in a field ahead. He reported that the landing was heavier than normal. During the landing roll a casting on the aircraft's nose wheel oleo failed, the nose gear leg collapsed rearwards and the propeller struck the ground. The pilot and two passengers were uninjured. Maintenance investigation by the aircraft operator revealed that the engine vibration and power loss had been caused by the cracking of a cylinder head at the rear of the engine. The power loss had occurred at low altitude, which had limited the options available to the pilot for an emergency landing area.

Turn backs resulting in off aerodrome landings

There were 15 partial engine power loss events where height could not be sustained long enough for the aircraft to return to the aerodrome. Three of these events resulted in fatal accidents, all involving a loss of control, and four of these events resulted in serious injury. Three out of the four serious injury accidents involved hard landings rather than striking objects, emphasising the importance of maintaining airspeed throughout to enable a proper flare and level out before touchdown. The other serious injury accident involved a ballistic recovery system[13] being deployed over water below the manufacturer's recommended altitude, which resulted in the aircraft entering the water in a near vertical attitude.

13 Large parachute deployed from above aircraft centre of gravity of general aviation aircraft in the event of an emergency such as a partial or complete engine failure.

Factors affecting the accidents above were manoeuvring at a low speed or steep bank angle and maintaining insufficient airspeed to flare the aircraft.

The hazards associated with these situations and suggested methods of avoiding these situations in the first place are contained in the section on loss of control below. However, it is important to note that early re-assessment of a situation is important to allow you, if necessary, to roll the aircraft's wings level, flare and land.

Turn backs resulting in on aerodrome landings

There were 145 partial engine power loss occurrences where the ground contact (landing or collision) was on the aerodrome. Of these 145 occurrences, one was a fatal accident and another resulted in serious injury. In the fatal accident, the aircraft had a surging engine and the pilot experienced subsequent loss of control during a turn at a height from which it could not be recovered. The serious injury occurrence also involved loss of control during a steep turn. Issues compounding the loss of control are discussed later in this paper.

Fifty turn backs following a partial engine power loss involved the pilot using another runway. The use of another runway should be considered during planning. If applicable to the aerodrome you are departing from or operating at as this will provide the opportunity to reduce the amount of turn required, as well as distance to travel to get the aircraft back on the ground.

The aircraft that were successfully landed on the aerodrome generally had enough power to maintain height or climb into the circuit and return to the take-off runway. However, some aircraft had sufficient height to return in a partially powered descending turn.

Eyes inside 5% of the time – maintain airspeed to help maintain control

Loss of control

Fifteen of the 242 partial engine power loss occurrences resulted in a loss of aircraft control. More than half of these loss of control accidents resulted in fatalities. Fatal loss of control accidents resulted mainly from aerodynamic stalls and spins, and were precipitated by the aircraft slowing, often from a pilot's attempt to stretch the glide or maintain height, or from entering a steep turn, with the associated increase in stalling speed at higher angles of bank.

Some difficulties specific to these accidents are outlined below.

- Having a surging engine, in particular with high thrust/weight aircraft, causing unwanted pitching of the aircraft, potentially inducing higher angles of attack over the wing of the aircraft.
- Having an engine producing an average mid-range power output[14], either through engine surging or other means is a characteristic of all of the loss of control fatal accidents associated with partial power loss after takeoff. This is likely to have made it difficult for these pilots to assess whether the aircraft could maintain height or make it around in a turn. One way to mitigate this is by checking the airspeed indicator and bank angle periodically.
- Some of the accident aircraft only had visual stall warning systems. One aircraft was not fitted with a stall warning indicator. Additionally, the aerodynamic buffet on the horizontal stabiliser and elevator resulting from flow separation over the wing is limited or not present in some aircraft, in particular high wing aircraft.
- Laminar flow aerofoils that do not handle well below the optimum speed and are characteristically relatively high in drag at higher angles of attack, which exacerbates the problem further.

14 'Mid-range power' is generally a power level where the aircraft cannot sustain height at a constant airspeed, and is aircraft specific.

Check your airspeed and bank angle

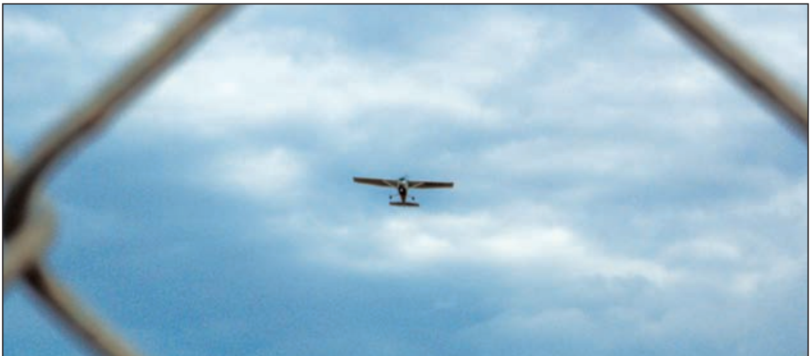
The most severe outcomes have occurred when the partial loss of power resulted in the aircraft descending slightly (or being maintained at altitude with increasing angle of attack resulting in airspeed bleeding off), rather than an almost complete loss of power, where it was clear that height could not be maintained. If you feel yourself wanting to stretch the glide, tighten a turn, or maintain height, check the airspeed indicator. If the airspeed has bled off from the glide speed, lower the nose, reduce bank angle if in a turn and re-consider landing options.

Planning for actions to take when dealing with partial engine power loss events and, to a lesser extent, knowing the particular aircraft characteristics will assist in reducing the risk of loss of control. Periodic checking of the glide speed and the angle of bank, and conducting gentle balanced manoeuvres will help to prevent loss of control, and give the best chance of walking away from the situation.

Case Study – loss of control

The pilot of an amateur-built Lancair 360 aircraft was conducting circuits at Bankstown aerodrome. It was the aircraft's first flight since being repaired after a landing accident. Following an over flight of the runway and a touch-and-go, the pilot conducted another touch-and-go and, shortly after lift-off at an altitude estimated by witnesses to be between 100 feet and 400 feet, the engine was heard to malfunction. Almost immediately, while still not above 500 feet, the aircraft rolled into a steep right turn. Engine power was heard to return, but sounded intermittent. After turning approximately 90 degrees, the aircraft rolled out of the turn momentarily to about wings level, before the turn steepened again to the right. The aircraft was observed to roll further to the right and descend steeply. The aircraft impacted a taxiway, the pilot was fatally injured and the aircraft destroyed. The aircraft stalled at a height insufficient to allow the pilot to recover.

ATSB investigation 200601688

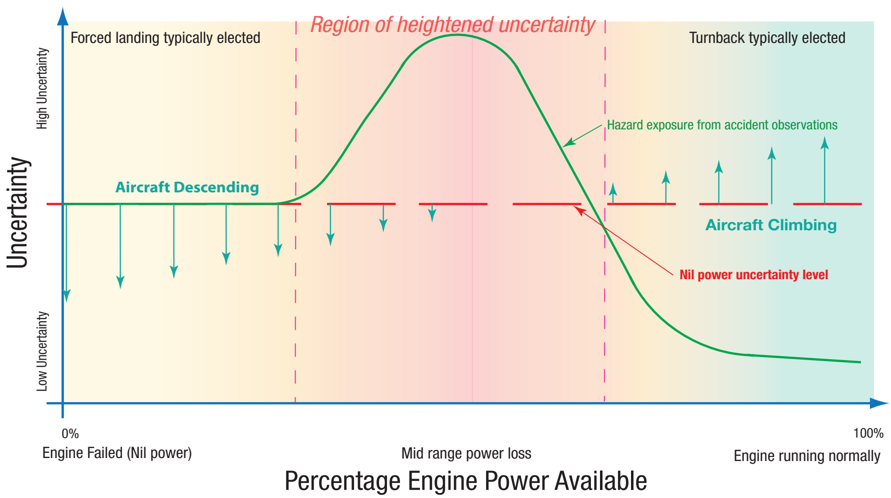


If nothing else, maintain airspeed and don't exceed your planned bank angle

Figure 3 below shows the conceptual hazard following a partial loss of engine power after takeoff, drawn from the findings of ATSB fatal accident investigations. When the amount of power lost is close to that experienced with a complete loss, the pilot is likely to readily identify the severity of the situation, and take action similar to that expected for a total power loss. At the other end of the spectrum, where the remaining engine power allows the aircraft to climb, more options are available to the pilot, such as climbing slowly into the circuit or carefully turning back to the aerodrome, while maintaining glide-speed and height.

All fatal partial power loss after takeoff accidents resulting from loss of control (eight out of nine fatal accidents) had an average mid-range power loss. This includes engine surging from high to low power settings and a consistent medium level power loss. Both of these scenarios present a complex problem to the pilot due to the aircraft not being able to maintain height without bleeding off airspeed – this inevitably results in the aircraft stalling. The solution: maintain glide speed, do not exceed the planned bank angle and stick to the minimum planned height for turning your aircraft.

Figure 3: Conceptual uncertainty by amount of power loss



Summary

Pre-flight checks prevent partial power loss

ATSB occurrence statistics indicate that many partial power losses could have been prevented by thorough pre-flight checks. Some conditions reported as causing partial power loss after takeoff are fuel starvation, spark plug fouling, carburettor icing and pre-ignition conditions. In many cases, these conditions may have been identified throughout the pre-takeoff and on-takeoff check phases of the flight sequence.

Pre-flight planning and pre-takeoff briefings

Even if a partial power loss does occur after takeoff, considering actions to take following a partial power loss after takeoff during the process of planning and the pre-flight safety brief gives pilots a much better chance of maintaining control of the aircraft, and helps the pilot respond immediately and stay ahead of the aircraft. Considerations include planning for rejecting a takeoff, landing immediately within the aerodrome, landing beyond the aerodrome, and conducting a turn back toward the aerodrome.

Stay in control

If nothing else, maintain glidespeed and plan a maximum bank angle against your personal minimums, which you will not exceed if a turn back is an option. Be prepared to re-assess the situation throughout any manoeuvre.

Australian Government

Australian Transport Safety Bureau

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608
Australia
1800 020 616
www.atsb.gov.au

The Australian Transport Safety Bureau is Australia's national transport safety investigator.

May11/ATSB39