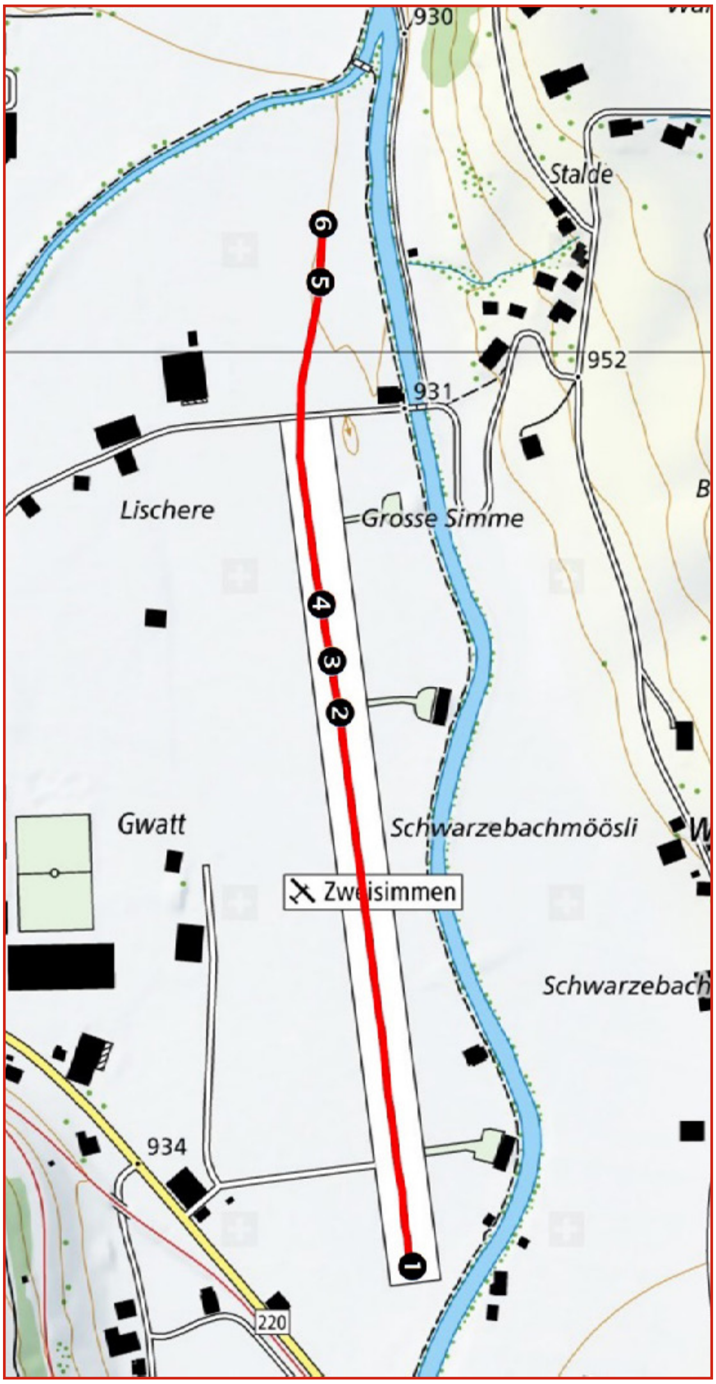
Pilot Induced Oscillations



1 GPS recording of the glider (red) with take-off position 1, impact tracks on the runway 2 3 4, landing position 5 and final position 6

In segelfliegen magazin 6/2023
an incident was discussed
in which a tow plane was brought down by short,
violent oscillations when the glider took off.
In this article, I will go into more detail
on the subject of Pilot Induced Oscillations –
hereafter referred to as PIO.

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The Swiss Transportation Safety Investigation Board's (STSB's) summary report on an incident involving an ASK 23 B in Zweisimmen is typical of many similar incidents involving PIOs. Course of the accident:

The take-off of the ASK 23 B glider, registered as HB-1796, took place on July 25, 2020 at 15:52. The take-off procedure was normal at the beginning. During acceleration, the glider's nose wheel initially remained on the ground until the glider abruptly lifted off the runway in a rapid rotational movement. Immediately afterwards, the glider oscillated around its pitch axis, touching down on the runway twice and taking off again. At this point, the tow plane also took off. While the tow plane began to climb, the glider descended without oscillating further and touched down on the runway again.

After touching down again, the glider took off again, whereupon the glider oscillated once more around its pitch axis, touching down and taking off again several times. During this time the glider continued to climb. The touchdowns of the glider increased continuously in severity until it came to impacts with clearly recognizable deflection of the wings and impact marks on the runway (***see points 2, 3 and 4 in Fig. 1***). The glider pilot then decided to abort the launch and released the tow rope. After releasing the tow rope, the glider entered a steep climb and reached an altitude of around 20 m above the ground at the end of the runway. The pilot tried unsuccessfully to counteract this movement with the elevator control and also extended the airbrakes. Finally, the glider pitched down and landed in the grass adjacent to the end of the runway. The pilot left the glider uninjured. The glider was badly damaged by the impact on the runway. The towplane landed uneventfully after one circuit.

In Wikipedia we find the following PIO definition:

In aviation, Pilot Induced Oscillation (PIO), also known as Aircraft Pilot Coupling (APC), is an undesirable behaviour of the aircraft that can result from an overreaction of the pilot to the effects of his control inputs. There is a risk of PIOs in particular if the aircraft's control systems only react to the pilot's commands with a delay, the pilot therefore increases the control impulse and tries to compensate for the aircraft's reaction (which is now stronger than originally desired) with a strong reaction in the opposite direction. As a result, the aircraft oscillates around one of its axes, which can lead to critical situations.

We all remember those first flights when we had to accelerate the glider from 50 to 65 kts (90 to 120 km/h). We carefully moved the stick forward until the airspeed indicator showed 65 kts (120 km/h). Then back a little, but the speed continues to increase! Finally the needle of the airspeed indicator moves back, at 120 push a little again. Of course, the speed has already dropped back to 55 kts (100 km/h) ... this goes on forever, and at the same time the pitch position is soon somewhere - until the flight instructor has mercy and stabilizes the aircraft with almost imperceptible movements within fractions of a second. Thank goodness this phase passes quickly for the student pilots. Although PIOs are triggered by the pilot's control inputs, the flight behaviour of the aircraft plays an important role. For example, airplanes with a short fuselage tend to oscillate around the pitch axis. PIO is not a "rookie mistake"; the pilot in the above-mentioned incident also had almost 1,000 flying hours. Space Shuttle pilots, for example, made over 1,000 training approaches in the simulator and in the Shuttle Training Aircraft (***Fig. 2***) before they were allowed to fly the real shuttle. Nevertheless, a PIO suppression filter had to be installed on the space shuttle after several incidents during the landing approach. Even airliners with their arrow wings would begin to oscillate around the vertical and longitudinal axis (the so-called "Dutch roll") if a yaw damper was not installed to suppress this movement with automatic rudder deflections.

Back to gliding. As explained above, the oscillations occur when the pilot/airplane system oscillates due to disturbances and incorrect reactions by the pilot. In free flight, for example, PIO can occur in strong turbulence. The potential danger is lower than near the ground (as long as the speed is not in a critical range). If the situation is recognized by the pilot, it can be stopped by locking the control stick in the neutral position. An inherently stable aircraft quickly stops oscillating and the flight attitude can be stabilized with sufficient altitude. PIO leads to critical situations, especially near the ground, i.e. during take-off or landing.

2 Shuttle Simulator Aircraft

By NASA : Public Domain:

What causes oscillation during the launch

During take-off, various influences can increase the risk of PIO: an incorrect trim position, a short tow rope or an aerotow using the winch hook increase the risk in the event of a malfunction. If PIO occurs, the amplitudes of the oscillations increase very quickly. Typically, such a situation builds up more and more until it is interrupted - by a release, the tow rope breaking or a crash. The oscillation can be stopped by deliberately blocking the control stick at the right moment. This is easier said than done. But how can PIO be prevented? For its report, the STSB found that various contradictory statements have been published. I quote:

Specifications and recommendations for longitudinal control at the start:

The ASK 23 single-seater glider has a non-retractable main landing gear as well as a nose wheel and a tail wheel. The nose wheel is only on the ground when loaded and must be lifted off the runway with elevator control inputs during take-off. There is contradictory information on this:

- The manufacturer recommends in the flight manual: "Pilots should try to keep the tail on the ground until take-off. This has many advantages. Take-off takes place at the earliest possible moment. The load on the landing gear is greatly reduced. The directional stability during taxiing is considerably increased. After take-off, climb to 1-2 m to avoid pitching oscillations caused by the ground effect and vortices of the towing machine."
- The US Federal Aviation Authority (FAA) points out in a training aid that the earliest possible take-off favours the development of a pilot induced oscillation (PIO) during aerotow launch: "There are several techniques that reduce the likelihood and severity of PIOs during aerotow launch. A pilot should not try to lift off until confident that flying speed and good aerodynamic control has been achieved."
- ...
- The Swiss Gliding Association (SFVS) also states that both "taxiing simultaneously on the main and nose wheel during take-off" and "taxiing in a two-point position during take-off" are "dangerous errors". Instead, the association recommends the following starting procedure: "Take the maximum load off the nose wheel when starting to roll and then immediately switch to rolling on the main wheel".

The report also points out that the differences between the various types of take-off are sometimes underestimated. The

pilot concerned mainly made winch launches on the grass runway at his home airfield in Olten. The disastrous flight was the first take-off at the Zweisimmen flight camp on a hard surface, in an aerotow. If the take-off technique is adapted (the aircraft is deliberately held longer on the nose or tail wheel) due to other elements - such as crosswinds - you must consider how this deviation from the standard procedure could affect the take-off process.
During an aerotow, it can immediately become very dangerous, especially for the tow pilot. It is therefore important to release immediately at the first sign of PIO - the less energy in the oscillations, the less damage there will be.
Experience has shown that the emotional factor of the first familiarisation with a single-seater aircraft should not be underestimated. The relatively inexperienced pilot is flying an unfamiliar aircraft for the first time and has to manage this alone. The seating position in this aircraft is usually quite different from that in the familiar two-seater; it often reacts more sensitively to control deflections. During the cockpit briefing, the flight instructor typically checks that the right arm rests loosely on the thigh, so that control movements are transmitted to the stick in a somewhat damped manner. If the support is missing, movements of the body can be unintentionally converted into control deflections. This can also be a trigger for PIO. It is worth making a few flights with a high-performance two-seater beforehand to get a feel for the finer controls.

On landing
PIO can also be triggered by various factors during landing. A stabilised approach with small variations in attitude and speed is a good basis for avoiding PIO. Strong turbulence makes a stabilised approach more difficult, as the elevator reacts more sensitively when approaching with increased speed. If, for these reasons, the initial ground contact is not made with the correct attitude, with too much energy or with a high sink rate, then we have all the ingredients to trigger PIO. Misjudgements, a gust close to the ground or – if everything else is right – a nasty bump in the wrong place can also spoil the game. As a pilot, you are practically always overwhelmed in these cases. The attentive flight instructor can stop an oscillation by locking the stick at the right moment and starting the landing again. However, this requires maximum concentration.
PIO is a problem that crops up again and again in accident reports. Because the processes are very complex and have many variables, there are no simple solutions. We therefore welcome any further tips on preventing or stopping PIO!

Link to the summary report of the STSB HB-1796: