ANOMALOUS VARIOMETER READINGS IN STRONGLY TILTED THERMALS

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Introduction

When a thermal is centered it might be expected that the variometer readings would be constant, and if it was not centered they would be expected to indicate a purely sinusoidal variation of climb rate with one maximum and one minimum per circle. However, it can be shown that when a glider is circled in a tilted thermal its variometer readings will include anomalous first, second and third harmonic components, even when it is centered.

In an earlier paper, entitled "Anomalous variometer readings when circling in tilted thermals" (XXIV OSTIV Congress 1995), the effects that tilted thermals have upon total-energy variometer readings were analyzed mathematically. However, the examples given at that time, assumed that thermal tilt angles would be limited to about 30°. In which case, the variometer readings are affected mainly by the variation of vertical flow and only slightly by the variation of horizontal flow, due to aircraft inertia, when circling in a tilted thermal.

For a Nimbus 3 sailplane with 45 kg/m wing-loading circling at 30 m/s with 45° of bank, the effect of the horizontal flow equals that of the vertical flow when the tilt is 52.5° from the vertical. However, in strong shears thermals can be tilted at angles that exceed 60°. The total energy variometer readings are then determined mainly by the horizontal rather than by the vertical flow variation. This leads to the apparent lift exhibiting three maxima and minima per circle, one pair of which being more prominent than the other two.

Wind shear and tilt

The magnitude and direction of thermal tilt is determined by wind shear. One region where there can be sufficient shear to cause detectable tilt occurs just below cloud base or, on a blue day, at the base of an inversion. At this level the thermals can be tilted against the wind. Thermals can also be subject to marked shears at the level of a mountain ridge, close to the ground or at the base of wave flow. At this level they are tilted with the wind.

If a thermal is vertical or only slightly tilted, then the effects of tilt will either be absent or too small to be

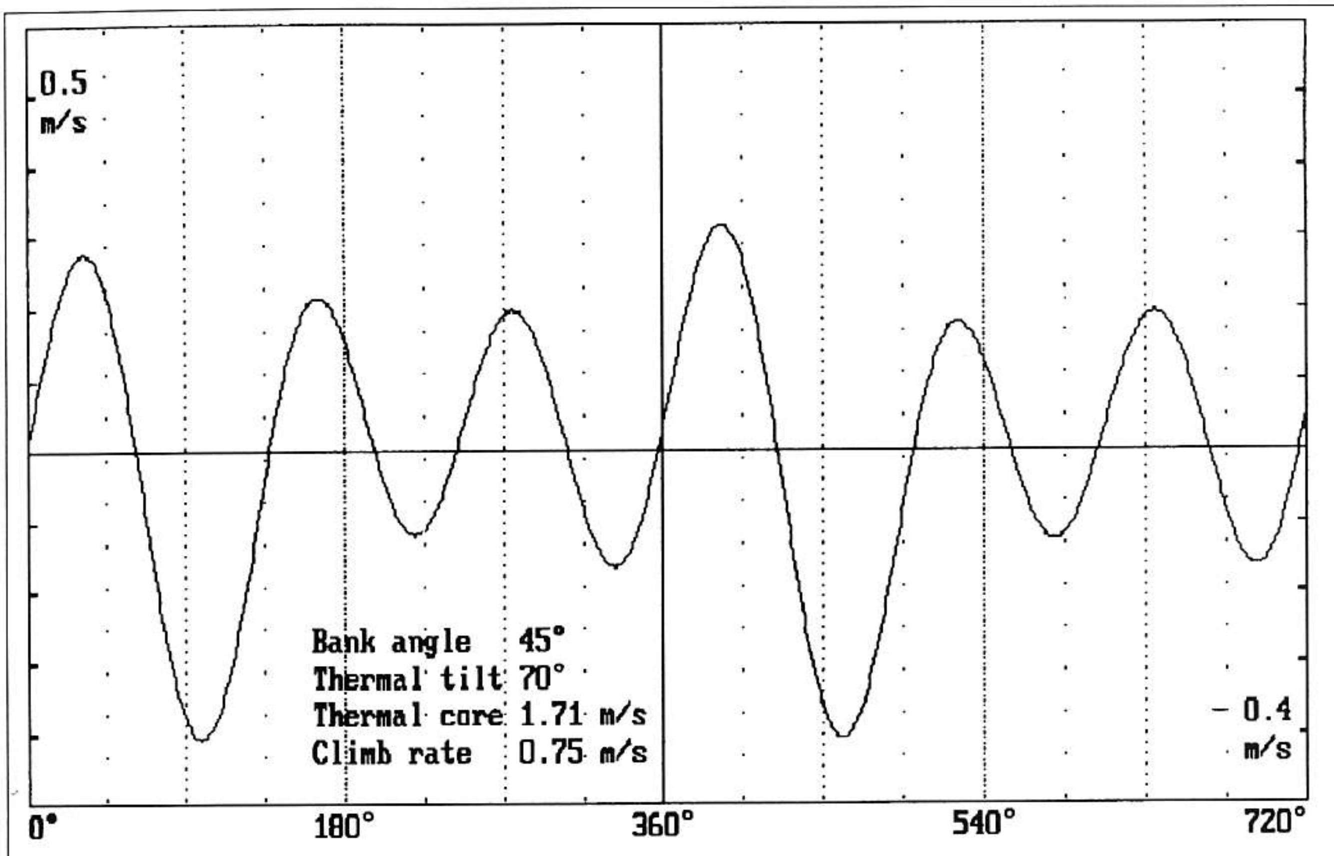

Figure 1..

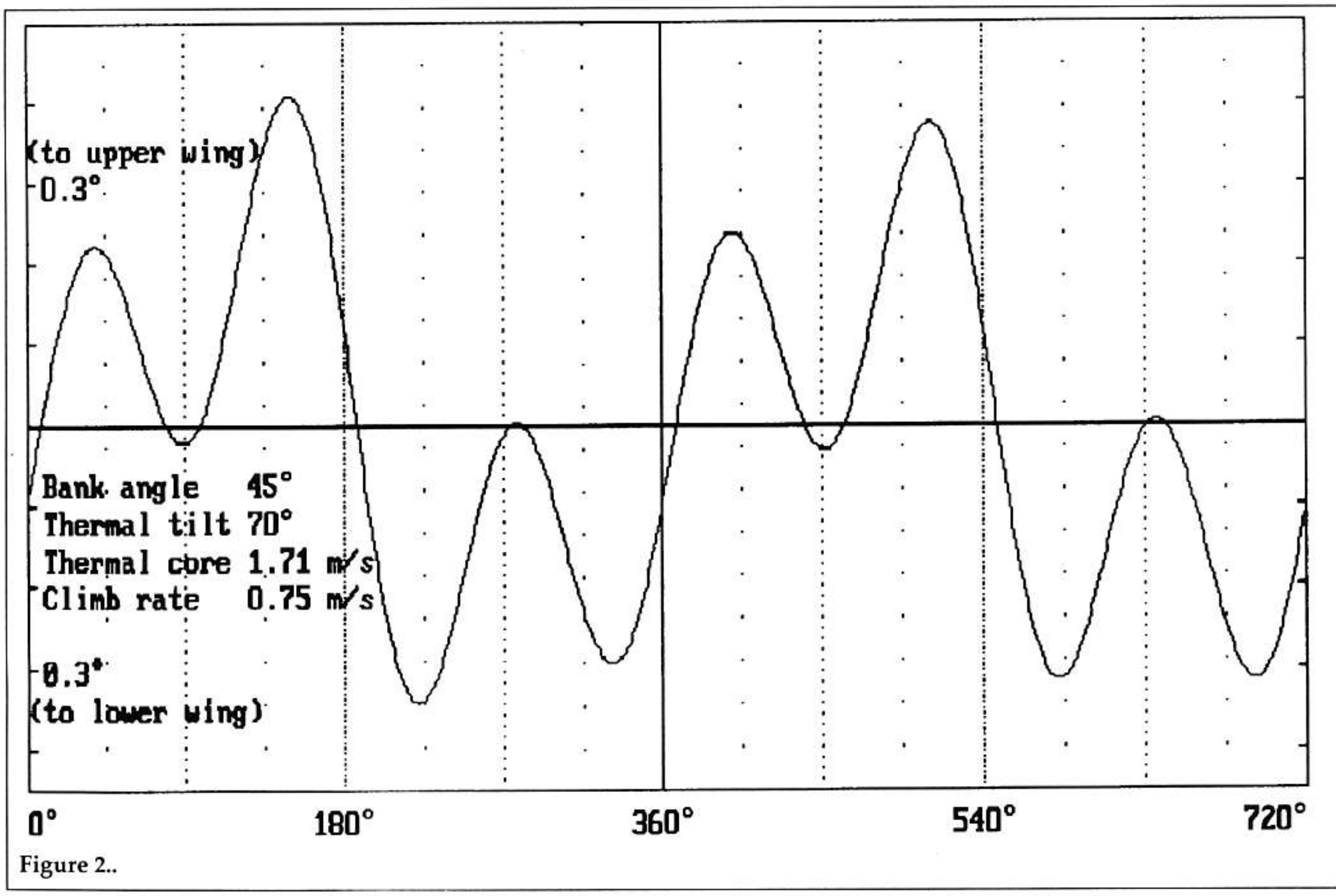

Figure 2..

observable, and experience indicates that this is usually the case. Also, when a thermal does tilt in a region of shear the climb rate reduces, indicating that it is time to move on. Consequently, very few glider pilots ever acquire sufficient experience to be able to deal with the effects of thermal tilt.

Centering techniques

In strongly tilted thermals the apparent lift exhibits three maxima and minima per circle, as shown in Figure 1, whose positions vary little as the glider drifts off-center in the direction of tilt. There is now a pronounced minimum that occurs 75° earlier than would be the case when circling off-center in a vertical thermal, and the most pronounced maximum, which is much less prominent than the minimum, occurs 30° later. Consequently, any corrections based upon either of these anomalous indications can lead to a correctly centered thermal being lost. Although, on average, the readings of a total energy variometer still indicate whether a glider is flying in lift or sink; the variations no longer give the pilot any good interpretable information about centering.

The best solution is simply to ignore the variometer and to observe the amount and direction of drift over the ground. This drift then needs to be eliminated by flying straight in the opposite direction for between one and two seconds after every circle. During straight flight, apart from minor changes in the time delay, variometer readings are free of anomalies. Also, since the horizontal cross-section of a strongly tilted thermal is very elongate, minor errors in distance correction have relatively little effect on the overall climb rate, provided only that the direction of correction is reasonably accurate. For the same reason, as the glider drifts off-center in the direction of tilt, the locations of the maxima and minima hardly change.

Yaw string deflections

In strongly tilted thermals the yaw string deflections become more pronounced, exhibiting three oscillations per circle, one pair of which is more prominent than the other two, and whose position varies little as the glider drifts off-center in the direction of tilt. These anomalous yaw string movements can be used to judge the timing of the recentering corrections required to compensate for the off-center drift in tilted thermals. To keep a strongly tilted thermal centered, the glider wings should be leveled for a couple of seconds between 30° and 45° after the yaw string crosses the centerline while moving towards the lower wing.

Conclusions

When the axis of a thermal is strongly tilted from the vertical, total energy variometer readings provide unreliable centering information. More reliable information may be obtained by observing either drift over the ground or yaw string deflections. The pilot should also be aware that the variometer can indicate a pronounced minimum some 75° earlier than appropriate for a normal centering signal.

Reference

West, J.M. (1995), "Anomalous variometer readings when circling in tilted thermals," XXIV OSTIV Congress, Omarama; and *Technical Soaring*, Volume 19, Number 3, July, 1995.

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