Lycoming or Continental Counterweight Detuning

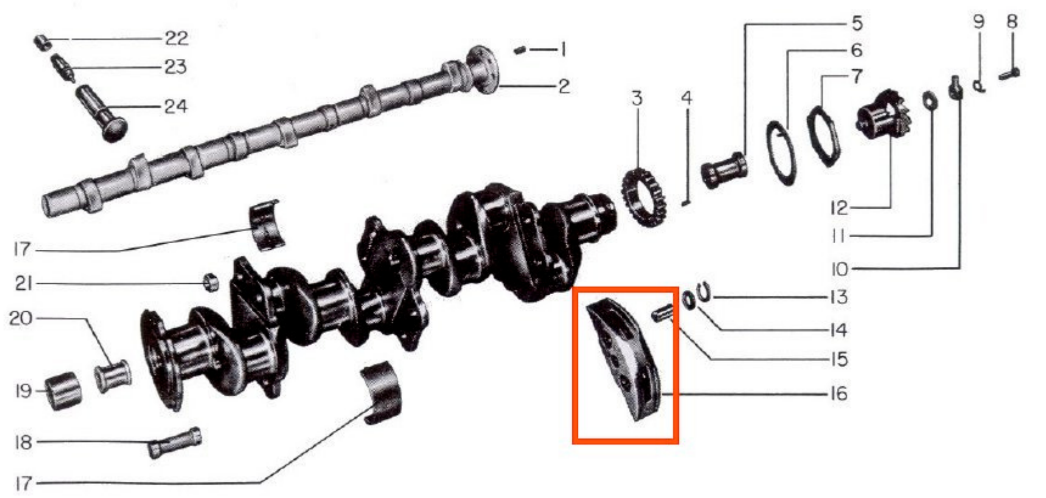
(by John Schwaner, reformatted by Steve Mestler)

Editors note: *The following article was submitted by member Bruce Hinds and was posted on the Mechanics Support Blog. The author is John Schwaner of Sacramento Sky Ranch fame. John is a wealth of knowledge and is now retired but I can tell you he knows what he's talking about. Diagrams have been "cleaned" up for easier reading. The first illustration below was missing from original document and replaced with Lycoming Overhaul Manual page. Bruce has some good advice below:*

"This is another important reason to respect our geared engines, the crank is counterweighted too. We already know the prop should never drive the engine and here's another reason that the counterweighted engines should never be used for flight training. You should never make any sudden changes to the power. Most direct drive engine airplanes are flown where you put the prop RPM up on approach in case you have to go around so you can add full throttle. Keep in mind that's only 200-300 RPM on a direct drive engine, our engines are 2600 to 3400 RPM, a change of 800 RPM. That makes it a lot easier to unload the prop and run the counterweight against its stop.

If we are operating according the performance charts that the airplane was certified with we really may not need all the power right away to do a go around. A Simuflight Bee only has a 100 lb increase in GW. I only use cruise RPM 2500 -2600 for approach and landing. If I need to go around, I can add full throttle and start my climb, then I will slowly tweek the RPM up to Max Continuous if I need to go that high. Keep in mind those performance charts were based on 215 HP. Check your GO-480 performance charts! Ours is 295 HP for T/O, 285 continuous and full throttle at only 2600 RPM shows 240 HP. We can beat the certification figures all day long.

The following article is interesting and it will make you think twice about ever pulling the power off in flight."



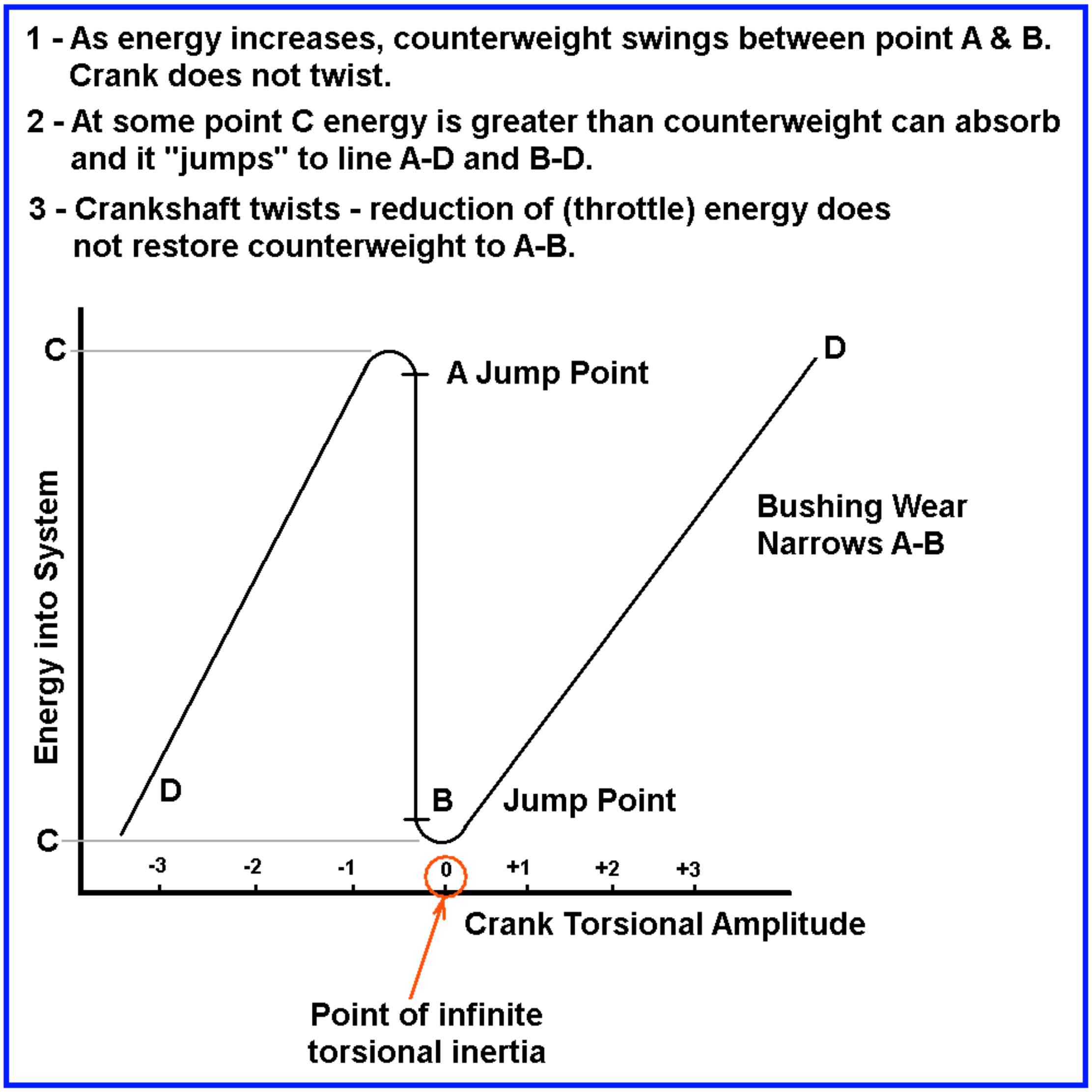
1. Dowel
2. Camshaft
3. Crankshaft Timing Gear
4. Woodruff Key
5. Rear Crankshaft Oil Tube
6. Crankshaft Gear Lockplate
7. Crankshaft Gear Retaining Nut
8. Hex Head Screw
9. Starter Jaw Lockplate
10. Starter Jaw Pin
11. Shim
12. Starter Jaw
13. Internal Retaining Ring
14. Counterweight Washer
15. Counterweight Roller
16. Dynamic Counterweight
17. Crankshaft Bearing
18. Crankpin Sludge Tube
19. Front Crankshaft Bushing
20. Front Crankshaft Oil Plug
21. Counterweight Bushing
22. Push Rod Socket
23. Hydraulic Tappet Plunger Assembly
24. Hydraulic Tappet Body

Crankshaft and Cam showing Counterweights

(Page from Lycoming GO-480 Overhaul Manual)

Illustration 1 above shows close-up of Lycoming counterweight showing plates (the part with 3 holes in it) that hold the pins in place. Pin diameter determines the pendulum length and thus the frequency. "Counterweights" are used on 6 cylinder Continental and Lycoming engines.

Your engine produces power in discrete combustion pulses that twist the crankshaft. Between pulses the crankshaft springs back. If one were to freeze crankshaft rotation so just the vibratory forces were left you would see that the back of the crankshaft rotates in the opposite direction as the propeller! If these pulses are at the same frequency as the natural frequency of the crankshaft then they have the capability of breaking the crankshaft at the fillet radius. In one test of a popular 6-cylinder aircraft engine, up to 20 degrees of crankshaft twist was measured!



Bifilar Pendulum Jump Curve

Bifilar Pendulums (centrifugal pendulum vibration absorbers) AKA "counterweights" pictured above absorb crankshaft torsional energy produced by the power stroke and eliminates or greatly reduces torsional twisting of the crankshaft.
There is a limit as to how much energy pendulums can absorb before they stop functioning. The graph below shows what happens when they are fed too much energy - Detune is the popular description although I prefer the word "jump".

During normal operation the Pendulum(s) operate between line A and B. When within the limits of power, the pendulum maintains crankshaft torsional amplitude (twisting) to near zero. The pendulum swings back and forth producing an opposing force to the twisting force thereby canceling it out. Pretty neat trick.

What happens if we increase the energy beyond C? Energy is increased by increasing horsepower at the resonant frequency of the crankshaft (lets say resonance occurs at 2,200 rpm in our example). The pendulum "jumps" over to line D and the crankshaft torsional amplitude now is free to twist and untwist putting great stress on the crankshaft. The pendulums are in a state called "detuning". Not only is crankshaft stress much greater but the pendulum itself has stopped swinging on the pins and is instead rattling against its restraint. This can result in circlip and retainer plate failure that releases the pendulum. This is what happened to Cape Air/Hyannis Air Service Inc. in their Cessna 402 (reference Teledyne Continental Motors Service Instruction SSI07-5). In fact it has been found that a "jumped" pendulum can amplify vibration amplitudes.

Once the pendulum jumps (detunes) great stress and destruction is occurring inside the engine without any outward indication to the pilot. But what happens if the pilot reduces the power or changes the rpm? The pendulums stay detuned! Once they jump to D they can only be restored to proper operation A-B by reducing the power to close-to idle.

Wear to pendulum bushings reduces the jump point (A-B). Normal bushing wear (and abnormal fretting wear) inside the engine shifts the pendulum's frequency resulting in not only a lower jump point but a slanting of the A-B line thus allowing more torsional forces. One reason why I don't recommend running pendulum equipped engines past engine TBO.

<u>Other failures possibly attributable to counterweight detuning</u>:

Impulse coupling attachment rivet failure
Crankshaft cracking
Propeller cracking
Left magneto oil seal failure on some Lycoming engines
Magneto drive shaft breakage
Magneto distributor gear teeth failure
Oil pump gear failure

What this means to the operator:

In the case of the Cessna 402 with TSIO-520-VB engines, don't operate at 2100 RPM and 27" Manifold Pressure (SSI07-5).

- Operate within the engine manufacturer's operational envelope. *"If I design a device and include a manual of operation, it is "safe" if operated within those boundaries. I have communicated clearly what those boundaries are."*
- Ignore well-intentioned advice to operate these engines outside of the manufacturer's power/rpm recommendations.
- Pendulum bushing wear limits the safe operational service life of the engine.
- Modifications to increase engine power output put the pendulums closer to the jump point.
- Modifications to increase engine power output reduce allowable pendulum bushing wear limit.

Notes:

1. http://www.egr.msu.edu/dvrl/pubs/Nester-etal_HI04.pdf (not available now)
2. Textron Lycoming Mandatory Service Bulletin No 245D (available on Lycoming website)

"Rapid opening or closing of the throttle can cause counterweight detuning…To avoid detuning during simulated engine failure, use the mixture control to shut off the engine and leave the throttle in normal open position until the engine has slowed down because of lack of fuel. Then, close the throttle to an idle condition. The throttle being open allows the cylinder to fill with air, maintaining the normal compression forces, which are sufficient to cushion the deceleration of the engine. Another result of rapid throttle movement is severe strain on the supercharger gears and associated gears because of the inertia force of the high speed impeller."

Further reading:

"Reduction of Periodic Torsional Vibration using Centrifugal Pendulum Vibration Absorbers": http://onlinelibrary.wiley.com/doi/10.1002/pamm.200910116/pdf
(Also available on the Seabee Club website as CPVA.pdf)