TAIL WHEEL STEERING CHAIN LINKS

An IAC member made the following report:

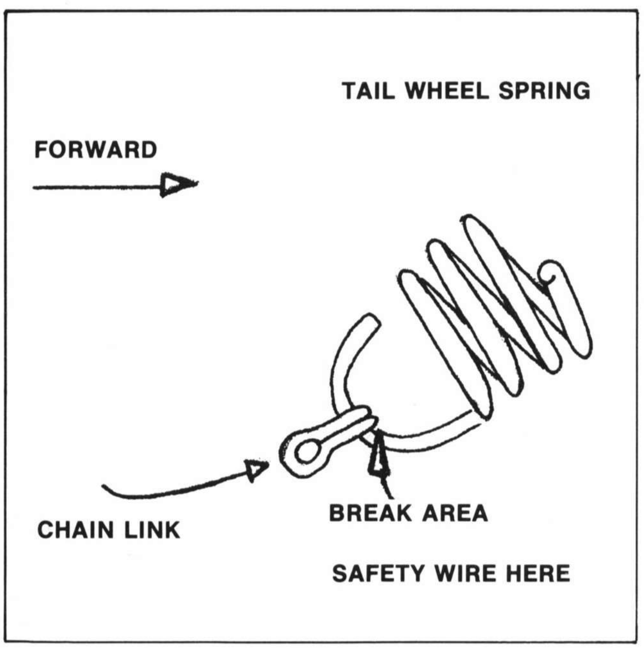
"If you have never ground looped your Pitts right in front of God, Poberezny, and everyone at Oshkosh you have an experience coming.

"The tail wheel steering chain link broke on roll out and it went around three times, luckily with no damage other than to the pilot's ego. However, the crowd liked it as they all applauded as I was walked in to park.

"These links are suspect as they are not really AIRCRAFT QUALITY. You buy them in a hardware store and they are nothing more than a dog chain. Yet they come in most tail wheel kits you buy.

"To preclude link breakage, the link that attaches to the spring (this is the one that seems to break first) is wrapped with safety wire. This is the area of more wear. The other end attaching to the teardrop clip at the tail wheel steering arm shows no sign of wear. On a Pitts this is usually a difficult area to inspect as the tail wheel assembly is usually covered with oil from the breather tube.

"While inspecting the chain links it is smart to run your finger over the sheet metal screws (three on a Maule) under the kickout pin as these have been known to drop out allowing the pin retainer plate to separate thereby rendering the steering mechanism inoperative. This has been corrected in later models with bolts."



IAC members may want to review two previous *Sport Aerobatics* Technical Safety articles dealing with tail wheel problems: August 1978 "Shimmy, Breakage & Other Tail Wheel Woes," and August 1979 "Pitts Parade".

Many thanks to the IAC member who sent in the above report. Remember, operation of the IAC Technical Safety Program depends on input from IAC members — PLEASE HELP.

UNDERSTANDING METAL FATIGUE

was written by Bill Freeman, EAA #148597. Bill is an engineer and a member of Chapter 200 of Overland, Kansas. Reprinted from the EAA Designee Newsletter

In the aircraft community the term "metal fatigue" is often used without any explanation, usually in reference to some part which has failed an inspection or perhaps a part which has failed in service. Some self-styled authorities will say that the metal "crystallized," which caused it to crack. You may envision the metal somehow getting "tired" and failing, and in some older aircraft it might seem that there was good reason to become tired, but these are far from the reality of metal fatigue.

Metal will not fail when the only load applied is a static or steady one, unless the tensile strength is exceeded. However, a rotating shaft with a side load on it or a part (bolt for example) with a fluctuating load may fail when the load applied is far below the tensile strength of the material. The fluctuating nature of the load is the key to metal fatigue.

Although there are details of metal fatigue that are not fully understood, the actual failure occurs something like this. A crack begins on the surface of the part, under conditions that we will discuss later. This crack is very tiny and very shallow at first, nearly undetectable. With each successive load fluctuation or cycle, the crack increases in depth and length a very small amount. As the crack increases in size, it eventually has separated enough of the load bearing portion of the part that the remaining metal can no longer sustain the load and fails suddenly and completely. If the part was a wing fitting, a connecting rod bolt or control bracket, the results could be spectacular. The purpose of magnetic particle ("Magnaflux") and dye penetrant ("Zyglow") inspection is to detect parts with fatigue cracks before they ultimately progress to failure.

Iron based alloys have a stress level below which the part can be loaded for an infinite number of cycles without fatigue occurring. Obviously this is desirable, and any critical components must be designed so that the stress level is below this endurance limit. For most steels the endurance limit is between 40 and 60 percent of the tensile strength for tensile strengths up to 200,000 psi. Above 200,000 psi tensile strength the endurance limit is approximately 100,000 psi. For non-ferrous alloys there is no true endurance limit, in the sense of a stress level below which infinite cycles are attainable. Endurance limits for these alloys usually refer to a stress level that ensures 10^8 (10 million) cycles before failure.

When a part fails from fatigue, the crack begins at a **stress concentration**. A stress concentration is self-explanatory, and may take many forms. On a shaft, a keyway, snap ring groove, a bearing shoulder, or abrupt change in section can be a stress concentration. Nicks, gorges, or holes can also be stress concentrations (also called stress risers).

On any part the surface finish is important if you want to avoid any stress concentrations. A highly polished surface finish has the best fatigue resistance. See the table below.

FRACTION OF ENDURANCE LIMIT ALLOWABLE

Surface Finish	Steel with Tensile Strength of 100,000 psi	Steel with Tensile Strength of 200,000 psi
Polished	1.0	1.0
ground	0.9	0.9
machined	0.75	0.65
hot rolled	0.55	0.35
as forged	0.4	0.25

The 100,000 psi column approximates the effect of surface finish on the fatigue life of an annealed alloy steel such as 4130. The figures are only presented to reinforce the understanding of the effects of surface finish on fatigue life, and are only approximate. It is readily apparent that there is a strong relationship between surface finish and the endurance limit (hence fatigue life). A part that will be perfectly satisfactory with a fully machined surface may fatigue and fail if left with an "as forged" surface. A part that fatigue cracks may be replaced with an identical part with a carefully polished surface and then may serve very well.

Any notch or hole in a structural component, however small, causes a stress concentration. In a very ductile material the first heavy load imposed may yield the material at the stress concentration, and thereby relieve the stress concentration. For a more brittle material, the notch or hole can cause an immediate failure when loaded heavily or may initiate a fatigue crack. The more brittle material is said to be more "notch sensitive" than the ductile material. Most steel aircraft structural parts are made of 4130 chrome molybdenum alloy steel, which is failry ductile in the annealed condition, and therefore are not as notch sensitive as if they were heat treated to a higher strength.

STAR WASHERS

from Dick Von Ber, Designee #1113, of 4403 Alvin Street, Saginaw, Michigan 48603

If a notch is present in a part, the degree of stress concentration is dependent on the radius of the notch or hole. The smaller the notch radius, the greater the stress concentration. A crack may have a "radius" at the leading edge of something like .00001" or even less, which concentrates the stress tremendously. By drilling through the leading edge of the crack, the notch radius may be increased to .0625" (1/16") an increase of over 6,000 times, and a huge reduction in the stress concentration. This "stop drilling" is common practice in non-critical aircraft parts such as cowlings, fairing and windscreens, but, of course, is not recommended for critical structural components.

In the same way that surface finish can affect the fatigue life of structural components, various surface treatments can also have a large impact on the fatigue resistance of a part. Shot peening, hammering or cold rolling can cause locked in compressive stresses on the surface of the part, and significantly increase the fatigue resistance of a component. Connecting rods and crankshafts (except the journals) are frequently shot peened for use in automotive racing engines.

"Minor" surface pitting on parts, especially heat treated, high strength parts can cause very real reductions in fatigue life, and should be polished out or the part replaced if failure would cause a structural failure or loss of control. Even if quite significant amounts of material are removed to grind and then polish out notches on highly stressed components, the component is likely to be more fatigue resistant and therefore safer than leaving a pit or notch with extra material still around it.

Plating can significantly reduce the endurance limit of a structural component. By "dressing up" that key part in your airplane with chrome or nickel plating, you may be reducing the endurance limit by as much as 35%. Also, (not necessarily related to fatigue, but on the subject of plating) avoid having any parts plated at an automotive plating shop. Plating causes hydrogen to enter the metal, causing it to become brittle, (quite apart from its reduction of endurance limit) which is very undesirable. The hydrogen can be removed by baking the parts, and aircraft plating shops do this, but we haven't space for a discussion of plating and post-plating heat treating. Generally, it is best to avoid plating any critical structural parts.

Understanding fatigue brings up another subject often confused in the aircraft community: threaded fasteners and why torquing them is important. The reason is usually to help prevent fatigue failure of the bolt. Of course on certain assemblies the application of uniform clamping loads to prevent distortion of a part (as on crankcase assemblies) can be more important than preventing fatigue. Generally the purpose behind torquing is to prevent the bolt from failing from fatigue.

A bolt can be thought of as a very, very stiff spring, which can be stretched by tightening the nut. Tightening the nut to a specific torque value stretches the "spring" a predictable (very small) amount. If the preload left in the bolt by stretching it is greater than the fluctuating axial loads applied in service, the bolt doesn't "see" these loads, and it will never fatigue.

An analogy can show this more clearly. Imagine an old-fashioned spring type hanging fish scale with a 20 pound weight hung on it. The pointer pulls down to the 20 pound mark and the spring compresses the distance from the zero to the 20 mark on the scale. If you were to carefully cut a small block of wood and prop it between the scale frame and the hook, then remove the 20 pounds, the spring stays compressed, and the scale still reads 20 pounds. The scale is now **preloaded**, like a torqued bolt. If you now hang a 15 pound load on the scale, nothing happens, and the pointer still reads 20 pounds; the scale doesn't "see" the load. As long as the applied load is less than the preload (20 pounds in this example), the scale is unaffected.

For a bolt, as long as the fluctuating axial loads applied to it in service are less than the preload applied when the bolt was torqued, it never "sees" the load and will not fail due to fatique. Any improperly torqued threaded fastener can fail due to fluctuating loads. Engine components such as cylinder base studs, connecting rod bolts and main bearing through bolts or studs are examples of fasteners that must be carefully torqued to prevent fatigue. If a proper torque value is not available, **and the clamped part will not be damaged**, over torquing is better than under torquing from a safety standpoint. The importance of preloading bolts cannot be overemphasized, since a high preload improves fatigue resistance and the locking effect. Please don't take this as a license to wring off every bolt in your airframe with a 36" Crescent wrinch, crush the valve cover gaskets by over tightening and warp the crankcase by exceeding recommended torque values — all to beat fatique. Use proper torgue values for the fastener size used if at all possible.

Hopefully I have shed some light on the subject of metal fatigue and provided some useful insight for the homebuilder. Don't go out and polish your fuselage tubes on your project to protect against fatigue, but do be aware that highly stressed parts must be treated sensibly and carefully to avoid fatigue problems.