

## Oleo Strut Basics

An oleo strut is a pneumatic air–oil hydraulic shock absorber. The primary pur-

pose of the oleo strut, as you are probably already aware, is to absorb the landing loads on an aircraft. The force, which the aircraft structure is subject to, can be expressed in Newton's 2nd law of physics  $F = M A$  or Force = Mass X Acceleration. Acceleration is simply the change in velocity over time. If we can double the time interval for deceleration of the aircraft through the landing gear by lengthening the shock strut, you can see that we can reduce the total force exerted on the structure by half. This is the basis for incorporating the long struts on STOL (Short Takeoff and Landing) aircraft like the Just Aircraft SuperSTOL and the Fieseler Storch. Watching these aircraft performing short field operations, you can see what appears to be near vertical approaches, culminating in a very impressive squat of the aircraft as the long stroke landing gear struts absorb the landing loads.

Although there's been many variations upon the oleo strut, there is some particular genius in its design. The basic physics incorporated in the operation of the oleo strut is what has made it so popular in so many different designs from the smallest aircraft to the largest. This basic design concept (Figure: 1) is so efficient that even the most modern of aircraft use the same basic principles that adorned aircraft landing gear designed and built as far back as the 1930s.

***"It is the fluid and only the fluid that is responsible for the struts' amazing ability to absorb these landing loads. A strut that has lost its fluid is virtually useless."***

Let's look at the basic operation of the oleo strut. (Figure: 2) Inside the strut we likely have a combination of Mill-H-5606 hydraulic fluid and dry air or nitrogen. The primary job of the air located in the upper chamber of the strut is to act as a spring. And the primary job of the hydraulic fluid, which is located in the lower chamber of the strut, is to regulate and transfer the loads from the lower half to the upper half of the strut and subsequently into the airframe. Located in between the upper and lower sections, but attached to the upper portion of the strut, is an orifice (Shown in Green). This orifice restricts the flow of hydraulic fluid from the lower half to the upper half of the strut. This basically lengthens



Figure: 1 Oleo Strut

the time interval during the compression stroke created by the landing gears impact with the ground. Many early strut designs simply stopped at this point using a fixed orifice to control the fluid transfer from the lower to the upper half of the strut. Later designs improved upon this concept by incorporating one more component called the metering pin (Shown in Pink) which takes the design to an entirely new

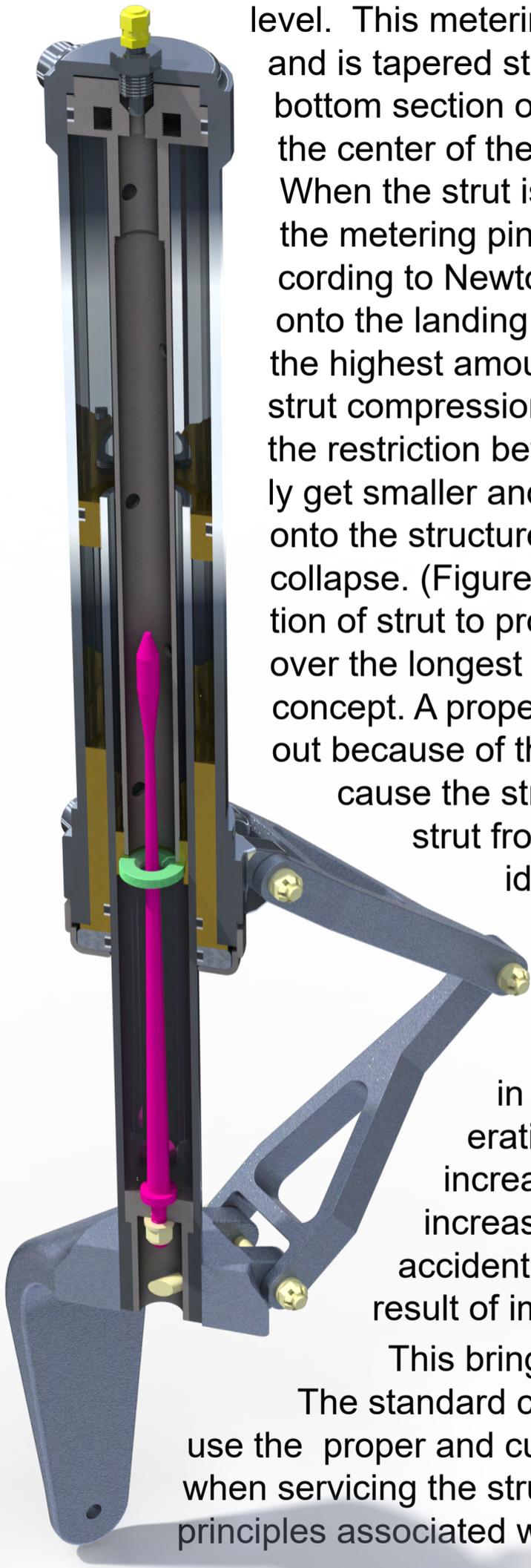
level. This metering pin is attached to the lower portion of the strut and is tapered starting at the top getting wider as it approaches the bottom section of the strut. This metering pin is co-located within the center of the orifice essentially creating a variable sized orifice. When the strut is fully extended, the gap between the orifice and the metering pin is relatively large allowing fluid to flow rapidly. According to Newton's 2nd law the greatest amount of force imposed onto the landing gear structure will be at the point where we have the highest amount of deceleration (initial impact). As the rate of strut compression decreases, so does the force. This design allows the restriction between the orifice and metering pin to progressively get smaller and smaller essentially maintaining a constant force onto the structure while exponentially decreasing the rate of strut collapse. (Figure: 3) This allows the entire length of the lower section of strut to progressively collapse absorbing the landing loads over the longest time interval possible. It's really quite a brilliant concept. A properly serviced strut is virtually impossible to bottom out because of this increasing restriction. Landing forces that could

cause the strut to bottom out would likely result in ripping the strut from the aircraft structure. Recognize that it is the fluid and only the fluid that is responsible for the struts' amazing ability to absorb these landing loads. A strut that has lost its fluid is virtually useless. A strut without fluid is the equivalent of welding the bottom half of the strut to the upper portion strut in the collapsed position. The time interval for deceleration, in this case, drop off dramatically. This, in turn, increases the loads imposed into the structure to also increase proportionally. We often wonder how many of the accidents, where we see a collapsed nose strut, are a direct result of improper servicing or simply loss of fluid.

This brings us to the topic of proper servicing of the strut.

The standard caveat certainly applies here: "You should always use the proper and current service manuals for your particular aircraft when servicing the struts." With this being said, let's consider some basic principles associated with servicing a strut. Keep in mind that during the

compression stroke of the landing gear the hydraulic fluid is non-compressible. This essentially means that over servicing the strut with hydrau-

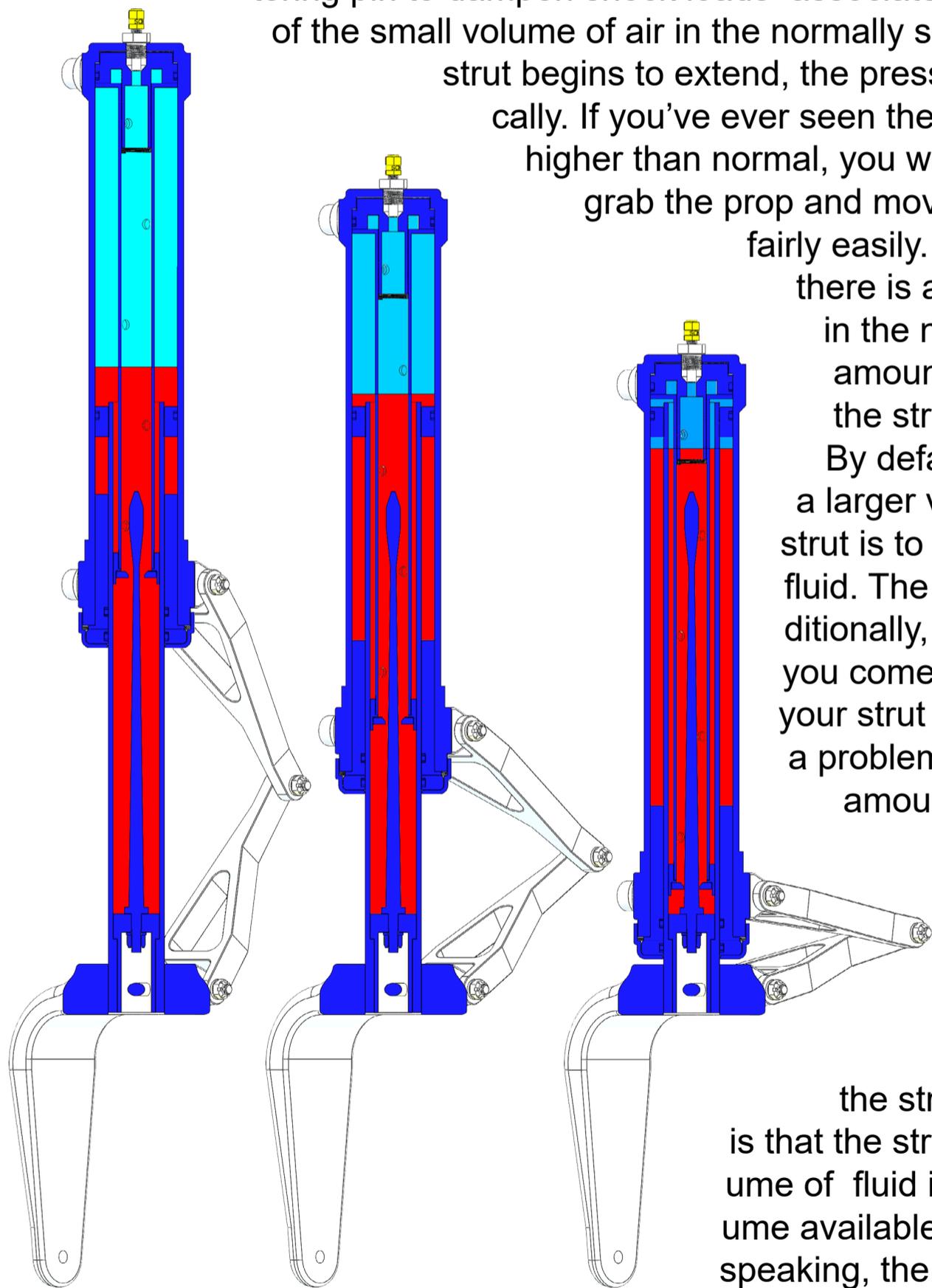


*Figure: 2* Oleo Strut Cut-A-Way

lic fluid could lead to a “liquid lock,” thus reducing the overall length of compression, compromising the struts ability to absorb the landing loads. Normal servicing of the strut might require that after adding fluid that we completely collapse the strut ensuring that any excess fluid is squeezed out before we add air or nitrogen. (Use of dry air or nitrogen is to reduce the potential for moisture getting into the internal structure of the strut causing corrosion). With the strut in the collapsed configuration and filled with fluid, the total volume available for air is really quite small. Once you have applied enough pressure to bring the strut up to the proper servicing height (approximately 25% of total stroke), the air simply acts as a spring to return the strut to a

height that will allow the fluid transitioning through the orifice and metering pin to dampen shock loads associated with taxiing. Because of the small volume of air in the normally serviced position, as the strut begins to extend, the pressure drops off dramatically. If you’ve ever seen the nose of Cessna sitting higher than normal, you would probably be able to grab the prop and move the nose up and down fairly easily. This simply means that there is a larger volume of air in the nose strut reducing the amount of pressure change as the strut moves up and down. By default, the only way to get a larger volume of air within the strut is to reduce the volume of fluid. The strut is low on fluid! Additionally, there is too much air. If you come out to the ramp and find your strut has collapsed, you have a problem not associated with the amount of air in the strut. The

initial urge is simply to service the strut with more air. However, you probably still have the proper amount of air inside of the strut. What has happened is that the strut has lost a small volume of fluid increasing the total volume available for the air. Generally speaking, the most probable source of leaking are the O-rings where the lower strut goes into the upper strut housing. All of the other seals



*Figure: 3 The Air - Oil Interaction During Operation*

within the strut are static with a very low likelihood of failure. Because the air is on top of the fluid, the first thing to go is always going to be the hydraulic fluid.

Although it's purely anecdotal, we see a direct correlation with the aircraft owners who wash the aircraft on a regular basis and a higher number of struts seal failures. We hypothesize that the cause of the strut seal failure is due directly to the owner of an aircraft, cleaning and washing, not only the aircraft, but the landing gear struts as well. If you were to completely clean the chromed portion of the oleo strut, you will be left with a very dry surface. As you confidently fly off for your "hundred dollar hamburger" and to show off your nice clean airplane to all of your buddies, you probably don't even realize that you have just set yourself up for a potential strut seal failure. If you inadvertently make a harder than normal landing, you may exercise the landing gear into the portion of the strut that has just been spotlessly cleaned. It is a common occurrence on dry struts, where the landing gear is exercised aggressively, that the internal O-rings will grab onto the nice clean chromed surface causing them to stick and roll. When the O-ring rolls, it normally does it in just one section causing the round O-ring to now take a twist. This twist now becomes a pathway for the hydraulic fluid and air to escape. The result, of course, is a collapsed landing gear strut. Once the O-ring has become rolled or twisted, the only fix, typically, is to disassemble the strut and install new O-rings. Ironically, the aircraft owner who never does any maintenance on his aircraft, and has oil puking out of the engine down onto the struts, never ends up having to replace nose strut seals because of his (automatic strut lubricating system) leaking engine. Of course, we jest, and do not recommend this as your primary solution to preventing strut seal failures. Most aircraft maintenance manuals, and even flight manuals, recommend after washing the aircraft struts to re-lubricate the chrome portion of the strut with a clean rag soaked sparingly in Mill-H-5606 hydraulic fluid. By maintaining a well lubricated strut, the O-rings will slide effortlessly along the chromed surface. It then becomes virtually impossible to roll an O-ring. Many aircraft checklists even incorporate this procedure as a preflight item. This procedure not only re-lubricates the strut and protects it from corrosion, but gives us an opportunity to remove any bugs, dirt, and old dried out hydraulic fluid which may have accumulated. Although not as dramatic a failure as rolling an old ring, dirt and debris that continuously get into the seals of the strut can cause the strut seals to become worn out and eventually leak.

The landing gear struts, in our aircraft, are such an amazing piece of engineering, however, all of that engineering won't do you a "lick of good" unless you keep them properly maintained and serviced.

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