

# [The landing gear design engineering essay](https://assignbuster.com/the-landing-gear-design-engineering-essay/)

This report explains about the Landing gear design. It will discuss about the types of landing gear, types of load it bears. It ill also discuss about the shock absorber and the absorbing system to absorb the impact during landing. This report will further tell the details of " Adaptive shock absorber". Discussion is made on the basis of data and facts.

The undercarriage or landing gear in aviation is the structure that supports an aircraft on the ground and allows it to taxi, takeoff and land. It is the part of the aircraft which absorbs most of the impact during landing. Landing gear is one of the aircraft structures that the safety of airplane is highly depends on it. A main issue in the design of a landing gear is to absorb and dissipate energy upon impact to prevent human injuries due to the excessive accelerations and this is done by shock absorber. Thus, the main and most critical part of landing gear is shock absorber so; the report mostly emphasis on shock absorber and focuses various gear design.

Historical Background

A retractable landing gear design was introduced in 1876, in a plan which was designed by Frenchmen Alphonse Pénaud and Paul Gauchot, [7]. The first aircraft that used a wheeled landing gear as a shock absorber was " Santos Dumont's 'No. 14 bis' " in October 1906, [7]. Eight year after that, wheeled landing gear particularly those encompassing a tail wheel, were common in aircraft design. As aircraft was becoming important weapon of wars, significant advances happened in landing gear and shock absorption. The first retractable landing gears and also various shock absorption methods such as restricted-flow hydraulic cylinders were introduced in World War II.

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## Fig. 1: Wheeled Landing Gear, [7]

## Operation

Whether electrically or hydraulically operated, the landing gear can usually be powered from multiple sources. In case the power system fails, an emergency extension system is always available. This may take the form of a manually-operated crank or pump, or a mechanical free-fall mechanism which disengages the up-locks and allows the landing gear to fall due to gravity. Some high-performance aircraft may even feature a pressurized-nitrogen back-up system. A hand-operated hydraulic pump, located between the front seats, is provided for manual extension of the landing gear in the event of a hydraulic system failure.

Operation of landing gear is described as retraction or extension of the landing gear. By pulling out on the gear lever and shifting it to the desired position. When the lever is positioned, the power pack will create pressure in the system and activate the landing gear to the selected position. Normally, the gear retracts fully or extends and locks, limit switches close, and the indicator light comes on indicating completion of the cycle. The safety (squat) switch, actuated by the nose gear, electrically prevents inadvertent retraction whenever the nose gear strut is com pressed by the weight of the airplane. When the nose gear is lifted off the runway during takeoff, the squat switch will close, which may cause the power pack to operate for ito 2 seconds and return system pressure to 1500 PSI in the event pressure has dropped below 1000 PSI. A " pull-off" type circuit breaker is also provided in the system as a maintenance safety feature. With the circuit breaker pulled out, landing gear operation by the gear pump motor is prevented. After maintenance is completed, and prior to flight, the circuit breaker should be pushed back in. [9]

## Types of undercarriage

## 2. 1 Tail-dragger or conventional gear

Tricycle arrangement or the tail wheel undercarriage is quite common and dominated aircraft design for the first four decades of flight and is still widely used on many small piston-engine planes. The tail-dragger arrangement (see Fig. 2) consists of two main gear units located near the center of gravity (CoG) that support the majority of the plane's weight. A much smaller support is also located at the rear of the fuselage such that the plane appears to drag its tail.

Taildragger or tailwheel landing gear

## Fig. 2: Tail-dragger or tail-wheel landing gear, [8]

## Advantage of tail-dragger

This type of gear is most attractive due its simplicity. They are relatively lightweight, and the two main gears can also be easily enclosed in streamlined fairings to produce low drag in flight. Another potential advantage results from the fact that the plane is already tilted to a large angle of attack as it rolls down the runway. This attitude helps to generate greater lift and reduce the distance needed for takeoff or landing. This attitude is also an advantage on propeller-driven planes since it provides a large clearance between the propeller tips and the ground. Furthermore, tail-dragger planes are generally easier for ground personnel to maneuver around in confined spaces like a hangar.

## Disadvantages of tail-dragger

The actual problem which comes with this landing gear layout is its handling characteristics. This design is inherently unstable because the plane's center of gravity is located behind the two main gears. If the plane is landing and one wheel touches down first, the plane has a tendency to veer off in the direction of that wheel. This behavior can cause the aircraft to turn in an increasingly tighter " ground loop" that may eventually result in scraping a wingtip on the ground, collapsing the gear, or veering off the runway. Landing a tail-dragger can be difficult since the pilot must line up his approach very carefully while making constant rudder adjustments to keep the plane on a straight path. Many tail-dragger designs alleviate these handling problems by fitting a tail-wheel that can be locked instead of swiveling on a castor. Locking the tail-wheel helps keep the plane rolling in a straight line during landing.

Another disadvantage of the tail-dragger is poor pilot visibility during taxiing since he is forced to peer over a nose that is tilted upward at a steep angle. It is also often difficult to load or unload heavy cargos because of the steep slope of the cabin floor. Similarly, pilots and passengers are forced to walk uphill during boarding and downhill after arrival. Many aircraft also rely on gravity to bring fuel from tanks to the engine, and some planes have been known to have difficulty starting the engine because it is uphill from the fuel supply.

## 2. 2 Tricycle or nose-wheel Gear

The most well known landing gear arrangement used in modern aircraft, the tricycle undercarriage includes two main gears just aft of the center of gravity and a smaller auxiliary gear near the nose. Cf. Fig. 3

## Advantages of tricycle

The main advantage of this layout is that it eliminates the ground loop problem of the tail-dragger. This arrangement is instead a stable design because of the location of the main gear with respect to the center of gravity. As a result, a pilot has more latitude to land safely even when he is not aligned with the runway. It also offers much better visibility over the nose as well as a level cabin floor to ease passenger traffic and cargo handling. Furthermore, the aircraft is at a small angle of attack so that the thrust of the engine is more parallel to the direction of travel, allowing faster acceleration during takeoff. In addition, the nose-wheel makes it impossible for the plane to tip over on its nose during landing, as can sometimes happen on tail-draggers.

Tricycle or nosewheel landing gear

## Fig. 3: Tricycle or nose-wheel landing gear, [8]

## Disadvantages of tricycle

The greatest drawback to tricycle gear is the greater weight and drag incurred by adding the large nose-wheel strut. Whereas many tail-draggers can afford to use non-retracting gear with minimal impact on performance, planes with nose-wheels almost always require retraction mechanisms to reduce drag. Some planes with tricycle gear also have difficulty rotating the nose up during takeoff because the main wheels are located so close to the elevator, and there may be insufficient control effectiveness. Similarly, the closeness to the rudder reduces its effectiveness in counteracting crosswinds.

Another critical factor when designing tricycle gear is to properly balance the load carried by the main gear versus the nose-wheel. Too little load on the main wheels reduces their braking effectiveness while too little on the nose-wheel reduces its steering effectiveness. Careful balancing of weight is also important to prevent the plane from tipping back on its tail while at rest on the ground as seen in Fig. 4.

Danger of tail sitting exemplifided by an improperly loaded 747

## Fig. 4: Danger of tail sitting exemplified by an improperly loaded 747, [8]

## Load types

Three types of loads act on aircraft landing gear during the landing. First one are vertical loads that are the result of non-zero touchdown speed, and are absorb and dissipate by shock absorbers and tires. These are the most important loads on the landing gear so; this report is more focused on shock absorbers. The second one are longitudinal loads that are due to 'spin up'[1]loads, and braking and rolling friction, these type of loads are resisted by a side brace and drag brace. The last types of loads are lateral loads which are because of crabbed landings, cross wing taxiing in addition to ground turning. These types of loads as same as longitudinal loads are resisted by a side brace and drag brace. (Fig. 5)

## Shock absorber

The landing gear shock absorber is an integral component of an aircraft's landing gear. As mentioned before the role of shock absorber is to absorb and dissipate energy upon impact, such that the accelerations of aircraft must be acceptable for aircraft structure, passengers and all other things that contained in aircraft (avionics, cargo, weapons etc.).

Aircrafts land in different conditions so; landing gear designer must consider all situations that aircraft could land, in order to achieved maximum energy absorption in critical situations.

Side brace

Shock absorberGR00868. jpg

## Fig. 5: Boeing B777 landing gear (from Goodrich Co.)

## Absorbing system

There are different types of categories for shock absorbers, but one of the important categories for shock absorbers is:

## 5. 1 Passive shock absorber

There are many different types of passive shock absorbers for landing gears, such as solid spring, rigid axle or also tires, but the most effective passive shock absorber is " Oleo-pneumatic" so; in this section, " Oleo-pneumatic" shock absorber is explained.

## 5. 1. 1 Oleo-pneumatic shock absorber

This type of passive shock absorber is one of the most common in medium to large aircraft, and this is the result of high efficiency as they can absorb and remove vertical kinetic energy simultaneously. The efficiency of Oleo-pneumatic shock absorber is due to the combination of spring force (compression of gas) and the damping (flow of hydraulic fluid through an orifice).

The main structure of Oleo-pneumatic shock absorber contains different parts (Fig. 6)

Outer cylinder

Inner cylinder

Piston

Working fluid (gas, liquid)

Piston

Inner cylinder

Outer cylinder

## Fig. 6: Scheme of an oleo-pneumatic shock absorber, [2]

The outer cylinder encases the whole shock absorber and remains static with respect to the airframe during operation. This cylinder must sustain the internal pressure due to the compression of the gas and fluid. The inner cylinder can move in axial direction, as the vertical forces in the landing acts on inner cylinder so this cylinder must be able to withstand significant dynamic pressure. The piston is placed inside the outer cylinder and is stationary, there are several holes in piston head, these holes acts as an orifice, and during the landing these orifices provide significant damping to absorb energy. The inner cylinder contains the hydraulic fluid that is usually some type of oil, and the outer cylinder contains combination of gas and liquid. The gas is usually pure nitrogen.

In unloading condition because of the pressure of gas the inner cylinder is completely extended. When the load applies to the bottom of inner cylinder, the inner cylinder starts to move in axial direction. This causes that hydraulic fluid inside the inner cylinder going through orifices in the head of piston. Motion of fluid through orifices causes an effective damping that absorbs the majority of the landing energy. Absorption of energy is due to convert of vertical kinetic energy to heat energy within the hydraulic fluid. When the hydraulic fluid passes through orifice in the piston head, starts to compress the gas which is inside the outer cylinder. Compression of the gas acts like a spring and provides substantial resistive force.

Under design conditions passive Oleo-pneumatic shock absorbers have very high efficiency 80-90%, but in off design conditions, such as taxiing or typical landings their performance are going to be much less, because in off design conditions unnecessarily high loads are transferred to the aircraft structure, and cause fatigue problems that is one of the most series problems in aircraft structure.

## 5. 2 Active shock absorber

Classical concept for design of shock absorber is to select specific magnitude for damping and stiffness properties, these magnitudes are chosen such that the landing gear is optimized for landing cases with maximum weight and maximum speed. However, the impact varies significantly between landings. Thus, in most of landing conditions, shock absorbers work in non-optimal situation. The result of this non-optimal situation is transferring of high damping forces to structure which influences the fatigue process. Active shock absorber works by changing the viscosity and damping in different landing conditions to minimize the peak force transferred to the aircraft structure during touchdown and to reduce fatigue factor.

## 5. 2. 1 Adaptive shock absorber

The term " Active adaption" refers to the particular case of actively controlled energy dissipater, where the need for external sources of energy is minimized and the actuators instead of applying externally generated forces, they modify local mechanical properties.

The force generated by landing gear depends on the pressure difference between the fluid and gas in the inner cylinder and outer cylinder. This force can be controlled via proper management of the fluid and gas that is transferred between cylinders. The value of pressure drop can be modified via changing the gas pressure in the outer cylinder, or by changing the resistance of the fluid across the orifices; this is done by using very fast actuators or by changing the rheological properties of the fluid.

Problem that mentioned for passive shock absorber can be significantly reduce by using of Adaptive Impact Absorption(AIA) which focus on 'active adaption' of energy absorbing structures to actual dynamic loading by employing system of sensors discovering actual position of aircraft and applying control system to change shock absorber properties.

Shock absorbers based on Magneto Rheological Fluids (MRF) or piezo valves, can be successfully used in adaptive landing gears. By using MR fluid in shock absorber is possible to control pressure drop between inner and outer cylinder. This type of fluid has a feature of changing its viscosity when it is subjected to an external magnetic field. By using magnetic field around orifices, it is possible to change the local viscosity of the fluid. Another technology for control the fluid that moves and transfers in shock absorber is using fast valves actuated by piezo elements; ADLAND project was the first experiment that used this technology.

## Fig. 7: Magneto Rheological Fluids (MRF) - based ALG, [4]

## Fig. 8: piezo - actuators based ALG, [4]

In spite of the active shock absorber features, this type of shock absorbers have some problems so; the designers must take into account a series of aspects in designing the control system. The first problem is related to the duration of the landing. In general, the landing impact lasts between 50 and 200ms, depending on the size of the landing gear and the landing conditions. It is difficult to use effectively active control system in this short time. Currently available high response valves on the market have delay time between 10 - 12ms but, by using High Performance Valves (HPV) based on piezo - actuator or MR fluid, time delay will be reduced to less than 5ms.

The second problem to be considered for the design of the active landing gear is calculation of exact position of the aircraft during landing in relation to the runway. Exact position is important because impact force is considerably different, depending on whether the plane lands on one or both main landing gears.

## Summary and conclusion

Landing gear serves three primary purposes--to provide a support for the plane when at rest on the ground, to provide a stable chassis for taxiing or rolling during takeoff and landing, and to provide a shock absorbing system during landing.

There are different strategies in designing of landing gears, but it is important to choose the best one for our design. For instance, active shock absorbers are very powerful to reduce the peak forces that are transferred to the aircraft, but with now a day's technologies we cannot use it for medium to large aircrafts.

One of the important diagrams in the designing of the landing gear is load deflection curve or work diagram. This diagram could be found during testing, by attaching an accelerometer to the shock absorber, and a simple displacement sensor to the inner cylinder. Performance statistics such as maximum loading, maximum deflection and efficiency can all be determined from this diagram.

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## Fig. 9: Load deflection curve for passive (left) and active (right) shock absorber, [3]

In Fig. 9, the left diagram shows the load deflection curve for passive shock absorber and the right diagram shows the work diagram for active shock absorber, it is worth mentioning that the first part of the both diagrams are same, this part of the gear compression cannot be significantly reduced.

In my opinion, I think the future technologies in passive shock absorbers are going to focus more in smart materials. It means to have materials that in different conditions, depends on the loads, have different behavior or materials such as viscoelastic materials that have both viscous and elastic behavior. But the problem in active shock absorbers is different, the main problem for this type is the design of control system and actuators, as the landing is very fast phenomena, so the delay in control system must be reduced, and also the actuators must be respond more rapidly.