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CAD SIMULATION & FEM ANALYSIS OF AIRCRAFT LANDING GEAR MECHANISM

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ABSTRACT

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear has wheels to facilitate operation to and from hard surfaces, such as airport runways. Other gear feature skids for this purpose, such as those found on helicopters, balloon gondolas, and in the tail area of some tail dragger aircraft. Aircraft that operate to and from frozen lakes and snowy areas may be equipped with landing gear that have skis. Aircraft that operate to and from the surface of water have pontoon-type landing gear. Regardless of the type of landing gear utilized, shock absorbing equipment, brakes, retraction mechanisms, controls, warning devices, cowling, fairings, and structural members necessary to attach the gear to the aircraft are considered parts of the landing gear system. Thus we are making them smooth and easily operated mechanism in Aircrafts.

KEYWORDS: Landing Gear, Shock Absorbing Equipment, Brakes, Retraction Mechanisms, Controls, Warning Devices, Cowling, Fairings and Structural Members.

INTRODUCTION

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear have wheels to facilitate operation to and from hard surfaces, such as airport runways. Other gear feature skids for this purpose, such as those found on helicopters, balloon gondolas, and in the tail area of some tail dragger aircraft. Aircraft that operate to and from frozen lakes and snowy areas may be equipped with landing gear that have skis. Aircraft that operate to and from the surface of water have pontoon-type landing gear. Regardless of the type of landing gear utilized, shock absorbing equipment, brakes, retraction mechanisms, controls, warning devices, cowling, fairings, and structural members necessary to attach the gear to the aircraft are considered parts of the landing gear system. These cams line up the wheel and axle assembly in the straight-ahead position when the shock strut is fully extended. This allows the nose wheel to enter the wheel well when The nose gear is retracted and prevents structural damage to the aircraft.

LANDING GEAR ARRANGEMENT

Three basic arrangements of landing gear are used: tail wheel type landing gear (also known as conventional gear), tandem landing gear, and tricycle-type landing gear. Numerous configurations of landing gear types can be found. Additionally, combinations of two types of gear are common. Amphibious aircraft are designed with gear that allows landings to be made on water or dry land. The gear features pontoons for water landing with extendable wheels for landings on hard surfaces. A similar system is used to allow the use of skis and wheels on aircraft that operate on both slippery, frozen surfaces and dry runways. Typically, the skis are retractable to allow use of the wheels when needed. Figure 13-2 illustrates this type of landing gear. References to auxiliary landing gear refer to the nose

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gear, tail gear, or outrigger-type gear on any particular aircraft. Main landing gear are the two or more large gear located close to the aircraft's center of gravity.

GENERAL LAYOUT AND DESIGN

The layout of the landing gear system determines the load transfer to the structure, ground stability and control. With exception of gliders, which may have just a central fuselage wheel and tailskid, the landing gear arrangement is tricycle, consisting of a main landing gear group located near the aircraft centre of gravity and a nose or tail landing gear (fig. 7.1). As a matter of fact, the tail element is almost obsolete, because the nose landing gear has a series of unquestioned advantages:

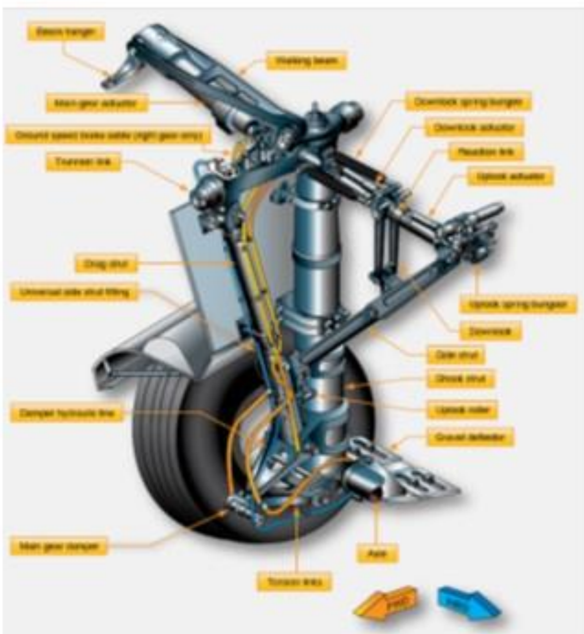

Fig. 1 Nomenclature of a main landing gear bogie truck.

- Lateral stability in taxiing;
- Stability in braking;
- Steady touchdown with no risk of aerodynamic bounce;
- High pilot visibility during taxiing;
- Horizontal floor (occupants' comfort and easy freight loading);
- Low drag during take-off acceleration.

A second observation concerns the number of struts. The most common configuration has double main landing gear and single nose gear. The only impediment to carbon brakes being used on all aircraft is the high cost of manufacturing.

Fig. II – Nose and tail wheel configurations

The lateral track of the main landing gear gives stability during taxing. The resultant force vector, due to weight and inertial forces, acting on the centre of gravity must fall inside the area delimited by the landing gear ground contact points, to prevent rollover. On the other hand the main wheels should not be too far from the aircraft centre line, to minimize roll and yaw instabilities during non leveled touch down and reduce wing root moment (if the landing gear is wing mounted). As far as the strut design is concerned, two solutions are mainly adopted: the telescopic and articulated leg, shown in fig. 7.5. The telescopic version is always lighter but requires higher ground clearance; then for small aircraft and helicopters the articulated version is more frequently adopted (from the figure it is clear that the piston stroke in the cylinder is lower than the wheel stroked).

EXTRACTION AND RETRACTION

A retractable landing gear is installed whenever a drag improvement is worthy. This means in all aircraft with exception of agricultural and small general aviation airplanes, where the installation of a movable landing gear would increase the costs beyond the requirements of the aircraft category. Landing gear extraction is a primary operation and always its actuation has high redundancy. There are different solutions for the mechanism to obtain suitable landing gear movement. Some are schematically shown in fig. 7.6. Many solutions are based on the four bar linkage (cases A to C), where one bar is represented by the aircraft frame. In other solutions (case D) one bar end can slide along a slot. More complex kinematics includes three-dimensional motion and the deflection of the bogie that for the main landing gear of large airplanes is made of double tandem wheels. Actuators, normally of the hydraulic type, control the extraction/retraction operation. In general the mechanism should be designed in such a way that gravity and aerodynamic drag favour extraction; if the conditions on gravity and drag are satisfied, the extraction is possible with no power from the hydraulic system; a diagram reporting piston load vs. stroke will be of the type shown in fig. 7.7, with a constant sign: this means that retraction is obtained by applying a force to contrast drag and

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movable equipment weight, while extraction can initiate by gravity and be completed by drag. The area under the load line represents the necessary work. If this is divided by the area of the rectangle defined by the max load and stroke, one obtains the efficiency of the kinematic mechanism, which commonly is in the range 70 – 80 %.

SHOCK ABSORBER LAYOUTS

The main role of the shock absorber is to zero the vertical component of the airplane velocity during landing, with no rebound and limited load transfer to the vehicle structure (and occupants). Its secondary requirement is to allow a comfortable taxiing. Different types of shock absorbers are available, but when costs and dimensions allow, a hydraulic system is commonly used. Very small aircraft with fixed landing gear may rely on the elastic properties of the landing gear legs and the damping effect of tyre sideslip on the ground, as schematically shown in fig. 7.8A. A low cost alternative to this method is to use an absorber made of a package of rubber blocks, which are compressed by the landing gear, so that the elastic effects is due to the rubber compression and damping to hysteresis and local friction.

The hydraulic solution is anyway the mostly adopted one, and fig. 7.8 B shows some of the many possible versions. Substantially the system structure is made of a movable piston that, when loaded, compresses a gas (nitrogen) in a cylinder and causes an oil flow through orifices. The system elasticity is due to the gas transformation and the damping effect to the liquid pressure losses. The complexity of the system increases with the requirements. A list of main requirements for an efficient and functional shock absorber follows:

- damping characteristics should be different in compression and extension; the total orifice area can be changed by inserting check valves in some orifices or valves that throttle the orifices in one flow direction.
- during taxiing the absorber should be softer; in this case also controllable orifices can be used; for instance the internal structure of the absorber can be shaped in such a way that, when the leg extension is that of the aircraft is in normal ground operation, the orifices have maximum area.
- for high landing vertical velocities, the shock absorber responds with high reaction forces due to oil viscosity; to attenuate the load transfer to the airplane structure, relief valves may be installed on the absorber, then flattening the reaction curve.
- to increase the energy absorption in crash conditions, multi-stage shock absorbers can be used; the first stage works in normal operation, the second and further stages start compression when a high load is developed; in some application (small aircraft and helicopters), the second stage is a composite cylinder in series with the main stage (crash cartridge).

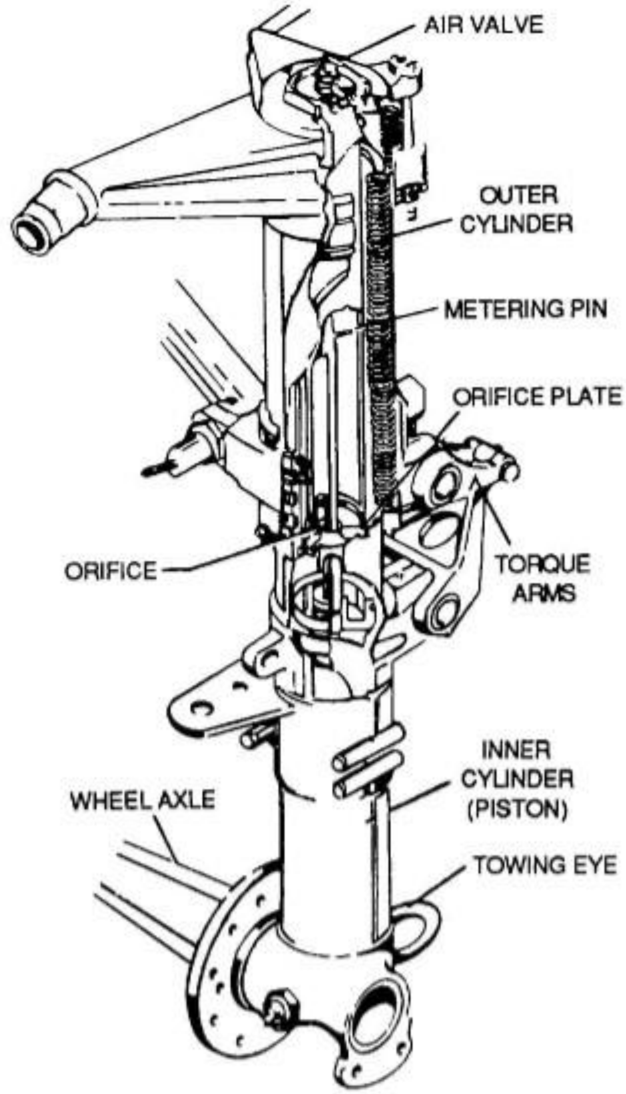

Fig. III A landing gear shock strut with a metering pin to control the flow of hydraulic fluid from the lower chamber to the upper chamber during compression.

The systems till now described are passive devices, with some hydraulic and mechanical solutions to obtain efficient energy absorption and comfortable

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taxiing. More advanced solutions, still under development, are based on active control of damping. Since the damping force is function of the orifice geometry and oil properties, a control of the damping characteristics of the shock absorber can be obtained in two ways:

1. Control of orifices area;
2. Control of fluid viscosity.

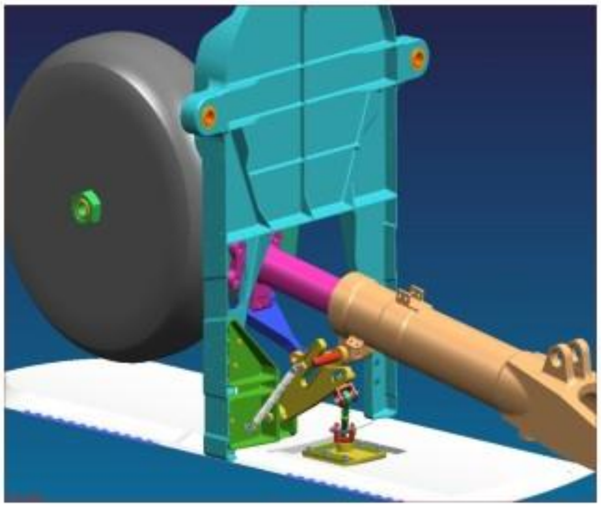

Fig. IV CAD Model of Landing Gear

The first solution is possible with the use of micro actuators that throttle the orifices. The second solution is possible with the use of electro rheological or magneto rheological fluids; these oils have properties sensitive to electric or magnetic fields respectively, and their peculiarity is to achieve quasi-plastic behavior when the field intensity is increased. Generating the field in the orifices sections allows changing significantly the damping behavior of the shock absorber by controlling the characteristics of a small volume of fluid. Both the systems are controlled on the basis of inputs from sensors of vehicle acceleration and velocity, and shock absorber conditions.

TRICYCLE-TYPE LANDING GEAR

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear. [Figure 13.6] Tricycle-type landing gear is used on large and small aircraft with the following benefits. Allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.

The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gear is directed through mechanical linkage to the rudder pedals. Heavy aircraft typically utilize hydraulic power to steer the nose gear. Control is achieved through an independent tiller in the flight deck. [Figure 13.7] The main gear on a tricycle-type landing gear arrangement is attached to reinforced wing structure or fuselage structure. The number and location of wheels on the main gear vary. Many main gears have two or more wheels. [Figure 13.8] Multiple wheels spread the weight of the aircraft over a larger area. They also provide a safety margin should one tire fail. Heavy aircraft may use four or more wheel assemblies on each main gear. When more than two wheels are attached to a landing gear strut, the attaching mechanism is known as a bogie. The number of wheels included in the bogie is a function of the gross design weight of the aircraft and the surface type on which the loaded aircraft is required to land. Figure 13-9 illustrates the triple bogie main gear of a Boeing 777.

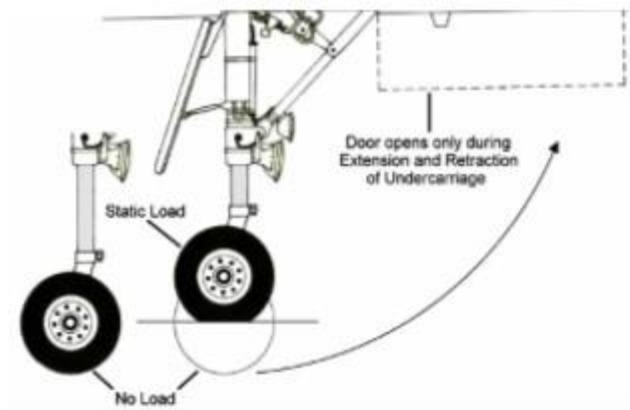

Fig. V Door Opening of Aircraft Wheels

BUNGEE CORD

The use of bungee cords on non-shock absorbing landing gear is common. The geometry of the gear allows the strut assembly to flex upon landing impact. Bungee cords are positioned between the rigid airframe structure and the flexing gear assembly to take up the loads and return them to the airframe at a non-damaging rate. The bungees are made of many individual small strands of elastic rubber that must be inspected for condition. Solid, donut-type rubber cushions are also used on some aircraft landing gear. The spring in the debooster aids in returning the piston to the ready position. If fluid is lost downstream of the deboost cylinder, the piston travels further down into the cylinder when the brakes are applied. The pin unseats the ball and allows fluid into the lower cylinder to replace what was lost. Once replenished, the piston rises up in the cylinder due to pressure build-up. The ball reseats as the piston travels above the pin and normal braking resumes. This function is not meant to permit leaks in the brake assemblies. Any leak discovered must be repaired by the technician.

SHOCK STRUT OPERATION

Illustrates the inner construction of a shock strut. Arrows show the movement of the fluid during compression and extension of the strut. The compression stroke of the shock strut begins as the aircraft wheels touch the ground. As the center of mass of the aircraft moves downward, the strut compresses, and the lower cylinder or piston is forced upward into the upper cylinder. The metering pin is therefore moved up through the orifice. The taper of the pin controls the rate of fluid flow from the bottom cylinder to the top cylinder at all points during the compression stroke. In this manner, the greatest amount of heat is dissipated through the walls of the strut. At the end of the downward stroke, the compressed air in the upper cylinder is further compressed which limits the compression stroke of the strut with minimal impact. During taxi operations, the air in the tires and the strut combine to smooth out bumps.

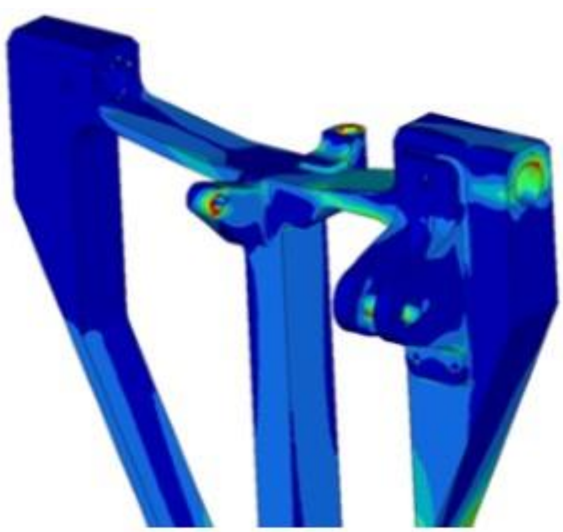

Fig. VI Analysis of Upper portion of Landing Arrangement

A lockout debooster functions as a debooster and a hydraulic fuse. If fluid is not encountered as the piston moves down in the cylinder, the flow of fluid to the brakes is stopped. This prevents the loss of all system hydraulic fluid should a rupture downstream of the debooster occur. Lockout debooster has a handle to reset the device after it closes as a fuse. If not reset, no braking action is possible. Large aircraft with power brakes require anti-skid systems. It is not possible to immediately ascertain in the flight deck when a wheel stops rotating and begins to skid, especially in aircraft with multiple-wheel main landing gear assemblies. A skid not corrected can quickly lead to a tire blowout, possible damage to the aircraft, and control of the aircraft may be lost.

SERVICING SHOCK STRUTS

The following procedures are typical of those used in deflating a shock strut, servicing it with hydraulic fluid, and re-inflating the strut.

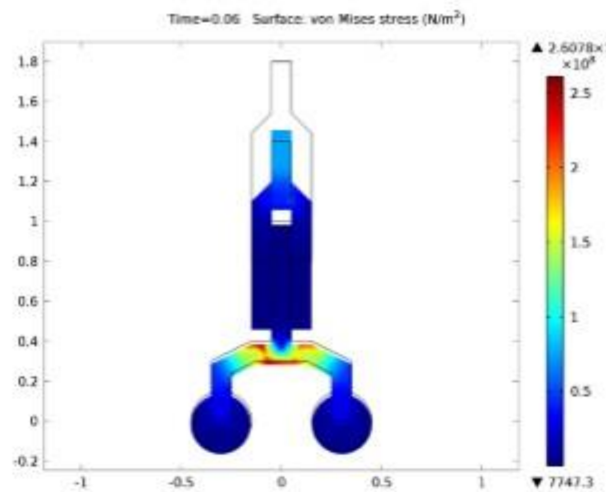

Fig. VII Stress Analysis Standing Barrel

Position the aircraft so that the shock struts are in the normal ground operating position. Make certain that personnel, work stands, and other obstacles are clear of the aircraft. If the maintenance procedures require, securely jack the aircraft. Remove the cap from the air servicing valve. Check the swivel nut for tightness. If the servicing valve is equipped with a valve core, depress it to release any air pressure that may be trapped under the core in the valve body. Always be positioned to the side of the trajectory of any valve core in case it releases. Propelled by strut air pressure, serious injury could result. Loosen the swivel nut. For a valve with a valve core (AN2687-1), rotate the swivel nut one turn (counter clockwise). Using a tool designed for the purpose, depress the valve core to release all of the air in the strut. For a valve without a valve core (MS28889), rotate the swivel nut sufficiently to allow the air to escape. When all air has escaped from the strut, it should be compressed completely. Aircraft on jacks may need to have the

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lower strut jacked with an exerciser jack to achieve full compression of the strut.

LANDING GEAR ALIGNMENT, SUPPORT, AND RETRACTION

Retractable landing gear consists of several components that enable it to function. Typically, these are the torque links, trunnion and bracket arrangements, drag strut linkages, electrical and hydraulic gear retraction devices, as well as locking, sensing, and indicating components. Additionally,

Nose gear has steering mechanisms attached to the gear. Alignment As previously mentioned, a torque arm or torque links assembly keeps the lower strut cylinder from rotating out of alignment with the longitudinal axis of the aircraft. In some strut assemblies, it is the sole means of retaining the piston in wheel would take in relation to the airframe longitudinal axis or centerline if the wheel was free to roll forward. Three possibilities exist. The wheel would roll either: parallel to the longitudinal axis (aligned); 2) converge on the longitudinal axis (tow-in); or 3) veer away from the longitudinal axis (tow-out). The manufacturer's maintenance instructions give the procedure for checking and adjusting tow-in or two-out.

Fig. VIII Landing Position of Gear

A general procedure for checking alignment on a light aircraft follows. To ensure that the landing gear settle properly for a tow-in/tow-out test, especially on spring steel strut aircraft, two aluminum plates separated with grease are put under each wheel. Gently rock the aircraft on the plates to cause the gear to find the at rest position preferred for alignment checks. A straight edge is held across the front of the main wheel tires just below axle height. A carpenter's square placed against the straight edge creates a perpendicular that is parallel to the longitudinal axis of the aircraft. Slide the square against the wheel assembly to see if the forward and aft sections of the tire touch the square. A gap in front indicates the wheel is towed-in. A gap in the rear indicates the wheel is towed out. Camber is the alignment of a main wheel in the vertical plain. It can be checked with a bubble protractor held against the wheel assembly. The wheel camber is said to be positive if the top of the wheel tilts outward from vertical. Camber is negative if the top of the wheel tilts inward.

Adjustments can be made to correct small amounts of wheel misalignment. On aircraft with spring steel gear, tapered shims can be added or removed between the bolt-on wheel axle and the axle mounting flange on the strut. Aircraft equipped with air/oil struts typically use shims between the two arms of the torque links as a means of aligning tow-in and tow-out. [Figure VIII] Follow all manufacturers' instructions. Alignment of the wheels of an aircraft is also a consideration. Normally, this is set by the manufacturer and only requires occasional attention such as after a hard landing.

GROUND LOCKS

Ground locks are commonly used on aircraft landing gear as extra insurance that the landing gear will remain down and locked while the aircraft is on the ground. They are external devices that are placed in the retraction mechanism to prevent its movement. A ground lock can be as simple as a pin placed into the pre-drilled holes of gear components that keep the gear from collapsing. Another commonly used ground lock clamps onto the exposed piston of the gear retraction cylinder that prevents it from retracting. All ground locks should have a red streamers attached to them so they are visible and removed before flight. Ground locks are typically carried in the aircraft and put into place by the flight crew during the post landing walk-around.

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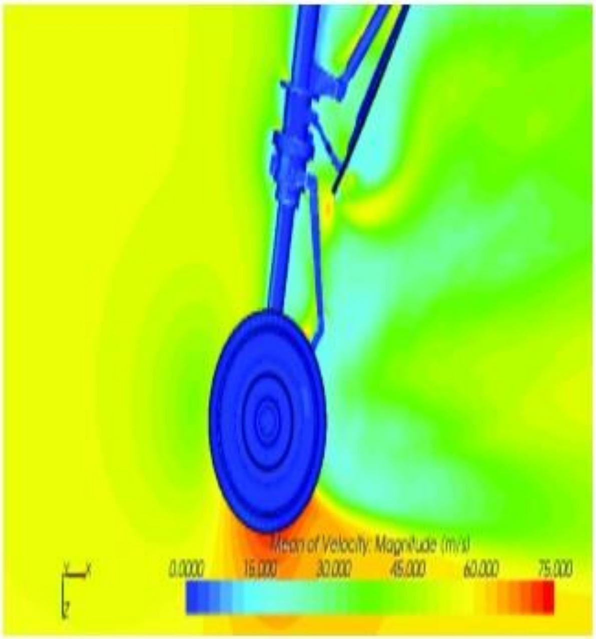

Fig. IX Normal Landing Point gear Velocity Analysis

LANDING GEAR POSITION INDICATORS

Landing gear position indicators are located on the instrument panel adjacent to the gear selector handle. They are used to inform the pilot of gear position status. There are many arrangements for gear indication. Usually, there is a dedicated light for each gear. The most common display for the landing gear being down and locked is an illuminated green light. Three green lights mean it is safe to land. All lights out typically indicates that the gear is up and locked, or there may be gear up indicator lights. Gear in transit lights are used on some aircraft as are barber pole displays when a gear is not up or down and locked. Blinking indicator lights also indicate gear in transit. Some manufacturer's use a gear disagree annunciation when the landing gear is not in the same position as the selector. Many aircraft monitor gear door position in addition to the gear itself. Consult the aircraft manufacturer's maintenance and operating manuals for a complete description of the landing gear indication system.

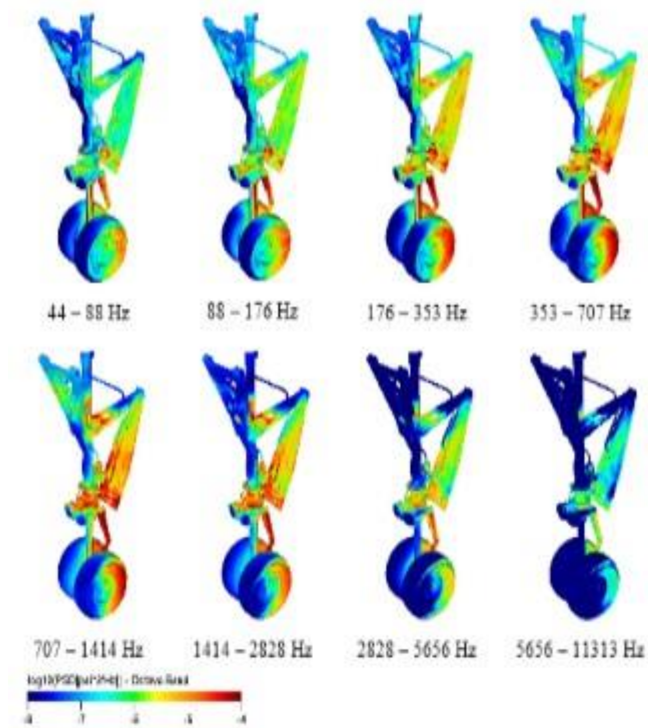

Fig. X Steady State Thermal Analysis of Landing gear

LANDING GEAR SYSTEM CONCLUSION

The moving parts and dirty environment of the landing gear make this an area of regular maintenance. Because of the stresses and pressures acting on the landing gear, inspection, servicing, and other maintenance becomes a continuous process. The most important job in the maintenance of the aircraft landing gear system is thorough accurate inspections. To properly perform inspections, all surfaces should be cleaned to ensure that no trouble spots are undetected. Periodically, it is necessary to inspect shock struts, trunnion and brace assemblies and bearings, shimmy dampers, wheels, wheel bearings, tires, and brakes. Landing gear position indicators, lights, and warning horns must also be checked for proper operation. During all inspections and visits to the wheel wells, ensure all ground safety locks are installed. Other landing gear inspection items include checking emergency control handles and systems for proper position and condition. Inspect landing gear wheels for cleanliness, corrosion, and cracks. Check wheel tie bolts for looseness. Examine anti-skid wiring for deterioration.

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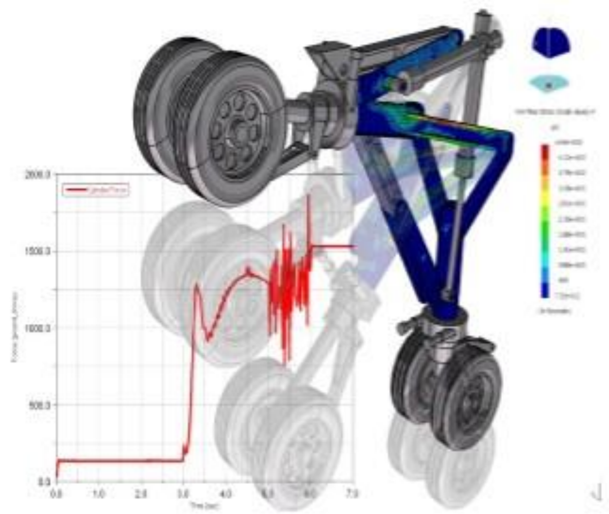

Fig. XI Force Analysis The parking brake lever on a Boeing 737 center pedestal throttle quadrant.

Wheel speed sensors are transducers. They may be alternating current (AC) or direct current (DC). The typical AC wheel speed sensor has a stator mounted in the wheel axle. A coil around it is connected to a controlled DC source so that when energized, the stator becomes an electromagnet. A rotor that turns inside the stator is connected to the rotating wheel hub assembly through a drive coupling so that it rotates at the speed of the wheel. Lobes on the rotor and stator cause the distance between the two components to constantly change during rotation. This alters the magnetic coupling or reluctance between the rotor and stator. As the electromagnetic field changes, a variable frequency AC is induced in the stator coil. The control unit can be regarded as the brain of the antiskid system. It receives signals from each of the wheel sensors. Comparative circuits are used to determine if any of the signals indicate a skid is imminent or occurring on a particular wheel. If so, a signal is sent to the control valve of the wheel to relieve hydraulic pressure to that brake which prevents or relieves the skid. The control unit may or may not have external test switches and status indicating lights. It is common for it to be located in the avionics bay of the aircraft. The Boeing anti-skid control valve block diagram in Figure 13-109 gives further detail on the functions of an antiskid control unit. Other aircraft may have different logic to achieve similar end results. DC systems do not require an input converter since DC is received from the wheel sensors, and the control unit circuitry operates primarily with DC. Only the functions on one circuit card for one wheel brake assembly are shown in Figure 13-109. Each wheel has its own Identical circuitry card to facilitate simultaneous operation. All cards are housed in a single control unit that Boeing calls a control shield.

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