SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF AEROSPACE ENGINEERING

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DAY: **43** TOPIC: ***DUTCH ROLL AND SPIRAL INSTABILITY***

Dutch Roll:

Dutch roll is an aircraft motion that is identified by a combination of a **continuous back and forth rolling and yawing motion.** In general, a Dutch roll is considered to be **dynamically stable**, meaning that the oscillations tend to decrease in amplitude. Most large airliners have a **yaw damper** installed that can artificially increase stability.

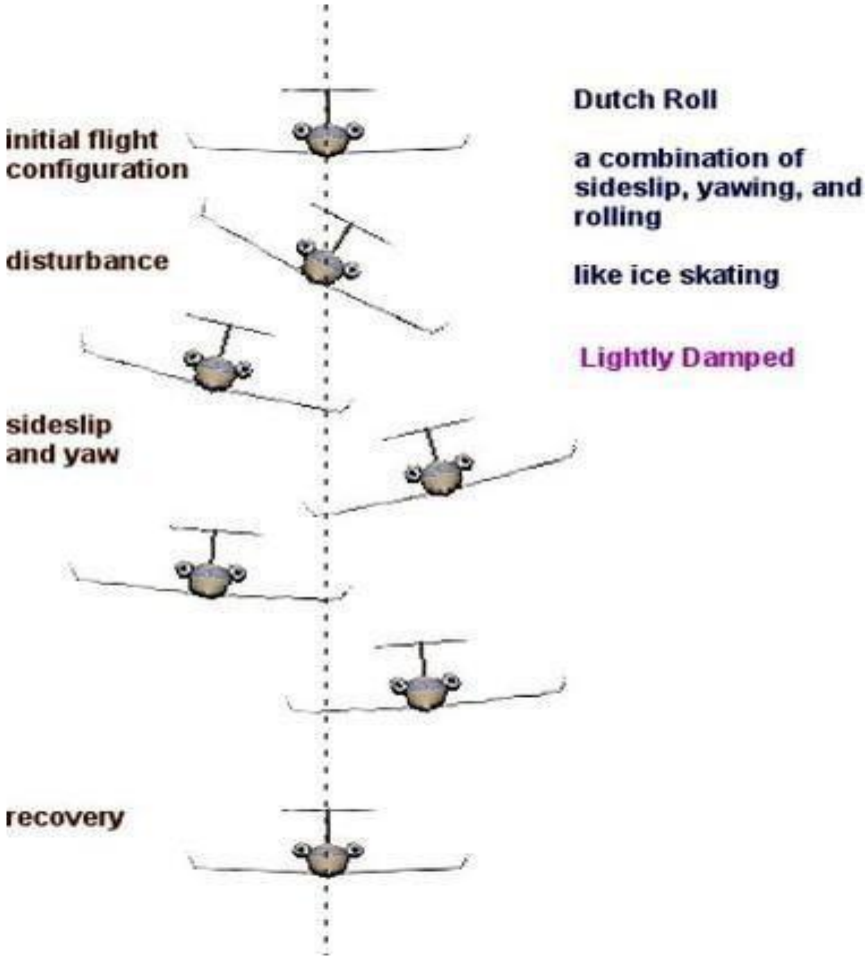
Aircraft that have wings placed above the center of mass, dihedral wings and swept wings tend to increase the roll restoring force, therefore increase the tendency of the aircraft to initiate a Dutch roll. This is the reason why high-winged aircraft are often slightly Anhedral, and swept wing aircraft rely on the operation of the yaw damper.

How it occurs:

In aircraft design, relatively **weaker positive directional stability** as opposed to **positive lateral stability** can result in a Dutch roll. Rolling the aircraft around the longitudinal axis means that a sideslip is introduced into the relative wind in the direction of the rolling motion.

Strong Lateral stability (Dihedral effect) begins to restore the airplane to wings level position. Weaker directional stability attempts to correct the sideslip by aligning the aircraft with the perceived relative wind. Since directional stability is weaker than lateral stability for the aircraft, the restoring yaw motion lags significantly behind the restoring roll motion.

The aircraft then passes through level flight as the yawing motion is continuing in the direction of the original roll. At this point, a sideslip is introduced in the opposite direction and the process is reversed. Periods can range from some seconds for light aircraft to several minutes for large airliners.



Dutch Roll

occurs when the aircraft is so laterally stable about the longitudinal axis that the wings, when displaced, become level before the nose of the aircraft is aligned with the relative wind again. Then, the nose starts to trace figure eights on the horizon.

DUTCH ROLL

A **Dutch Roll** is a combination of **rolling** and yawing (coupled lateral/directional) oscillations that normally occurs when the dihedral effects of an aircraft are more powerful than the directional stability

Dutch roll is a type of aircraft motion, consisting of an out-of-phase combination of "tail-wagging" and rocking from side to side. This yaw-roll coupling is one of the basic flight dynamic modes (others include phugoid, short period, and spiral divergence). This motion is normaly wel damped in most light aircraft, though some aircraft with well-damped Dutch roll modes can experience degradation indamping as airspeed decreases and altitude increases. Dutch roll stability can be artificialy increased by the instalation of a yaw damper. Wings placed wel above the centre of mass, sweepback (swept wings) and dihedral wings tend to increase the roll restoring force, and therefore increase the Dutch roll tendencies; this is why high-winged aircraft often are slightly anhedral, and transport-category swept-wing aircraft are equipped with yaw dampers.

In aircraft design, Dutch roll results from relatively weaker positive directional stability as opposed to positive lateral stability. When an aircraft rolls around the longitudinal axis, a sideslip is introduced into the relative in the direction of the rolling motion. Strong lateral stability begins to restore the aircraft to level flight. At the same time, somewhat weaker directional stability attempts to correct the sideslip by aligning the aircraft with the perceived relative wind. Since directional stability is weaker than lateral stability for the particular aircraft, the restoring yaw motion lags significantly behind the restoring roll motion. As such, the aircraft passes through level flight as the yawing motion is continuing in the direction of the original rol. At that point, the sideslip is introduced in the opposite direction and the process is reversed.

The most common mechanism of Dutch roll occurrence is a moment of yawing motion which can be caused by any number of factors. As a swept-wing aircraft yaws (to the right, for instance), the left wing becomes less-swept than the right wing in reference to the relative wind. Because of this, the left wing develops more lift than the right wing causing the aircraft to roll to the right. This motion continues until the yaw angle of the aircraft reaches the point where the vertical stabilizer effectively becomes a wind vane and reverses the yawing motion. As the aircraft yaws back to the left, the right wing then becomes less swept than the left resulting in the right wing developing more lift than the left. The aircraft then rols to the left as the yaw angle again reaches the point where the aircraft wind-vanes back the other direction and the whole process repeats itself. The average duration of a Dutch roll half-cycle is 2 to 3 seconds. The Dutch roll mode can be excited by any use of aileron or rudder, but for flight test purposes it is usualy excited with a rudder singlet (short, sharp motions of the rudder to a specified angle, and then back to the cantered position) or doublet (a pair of such motions in opposite directions). Some larger aircraft are better excited with aileron inputs. Periods can range from a few seconds for light aircraft to a minute or more forairliners.[*citation needed*]

Dutch roll is also the name (considered by professionals to be a misnomer) given to a coordination generally taught to student pilots to help them improve their "stick- and- rudder" technique. The aircraft is alternately rolled as much as 60 degrees left and right while rudder is applied to keep the nose of the aircraft pointed at a fixed point. More correctly, this is a rudder coordination practice exercise, to teach a student pilot how to correct for the effect known as adverse aileron yaw during roll inputs.

This coordination technique is better referred to as "rolling on a heading", wherein the aircraft is rolled in such a way as to maintain an accurate heading without the nose moving from side-to-side (or yawing). The yaw motion is induced through the use of ailerons alone due to aileron drag, wherein the lifting wing (aileron down) is doing more work than the descending wing (aileron up) and therefore creates more drag, forcing the lifting wing back, yawing the aircraft toward it. This yawing effect produced by rolling motion is known as adverse yaw. This has to be countered precisely by application of rudder *in the same direction* as the aileron control (left stick, left rudder - right stick, right rudder). This is known as synchronized controls when done properly, and is difficult to learn and apply well. The correct amount of rudder to apply with aileron is different for each aircraft.

The origin of the name Dutch roll is uncertain. However, it is likely that this term, describing a lateral asymmetric motion of an airplane, was borrowed from a reference to similar-appearing motion in ice skating. In 1916, aeronautical engineer Jerome C. Hunsaker published the folowing quote: "Dutch roll – the third element in the [lateral] motion [of an airplane] is a yawing to the right and left, combined with roling. The motion is oscilatory of period for 7 to 12 seconds, which may or may not be damped. The analogy to 'Dutch Rol' or 'Outer Edge' in ice skating is obvious."[1] In 1916, Dutch Rol was the term used for skating repetitively to right and left (by analogy to the motion described for the aircraft) on the outer edge of one's skates. By 1916, the term had been imported from skating to aeronautical engineering, perhaps by Hunsaker himself. 1916 was only five years after G. H. Bryan did the first mathematical analysis of lateral motion of aircraft in 1911.

Spiral Instability

occurs when the aircraft is very directionally stable. When the wing is displaced, the nose of the aircraft yaws toward the relative wind before the wings can level. As such, lowered wing moves faster through the air, and thus creates more lift and it raises. Then, it continues to lift, until the aircraft starts a spiral in the opposite direction.

SPIRAL INSTABILITY

Spiral instability exists when the static directional stability of the airplane is very strong as compared to the effect of its dihedral in maintaining lateral equilibrium. When the lateral equilibrium of the airplane is disturbed by a gust of air and a sideslip is introduced, the strong directional stability tends to yaw the nose into the resultant relative wind while the comparatively weak dihedral lags in restoring the lateral balance. Due to this yaw, the wing on the outside of the turning moment travels forward faster than the inside wing and as a consequence, its lift becomes greater. This produces an overbanking tendency which, if not corrected by the pilot, wil result in the bank angle becoming steeper and steeper. At the same time, the strong directional stability which yaws the airplane into the relative wind is actualy forcing the nose to a lower pitch attitude. We then have the start of a slow downward spiral which, if not counteracted by the pilot, wil gradualy increase into a steep spiral dive. Usualy the rate of divergence in the spiral motion is so gradual that the pilot can control the tendency without any difficulty.

All airplanes are affected to some degree by this characteristic although they may be inherently stable in allothernormalparameters. This tendencywould be indicatedto the pilot bythefact that the airplane cannot be flown "hands off" indefinitely.

Much study and effort has gone into development of control devices (wing leveler) to eliminate or at least correct this instability. Advanced stages of this spiral condition demand that the pilot be very careful in application of recovery controls, or excessive loads on the structure may be imposed. Of the inflight structural failures that have occurred in general aviation airplanes, improper recovery from this condition has probably been the underlying cause of more fatalities than any other single factor. The reason is that the airspeed in the spiral condition builds up rapidly, and the application of back elevator force to reduce this speed and to pul the nose up only "tightens the turn," increasing the load factor. The results of the prolonged uncontrolled spiral are always the same; either in-flight structural failure, crashing into the ground, or both. The most common causes on record for getting into this situation are: Loss of horizon reference, inability of the pilot to control the airplane by reference to instruments, or a combination of both. Specific instructions on preventing loss of control and the recovery from spirals have been explained in preceding chapters.

Spiral Divergence

Spiral divergence is characterized by an airplane that is very stable directionally but not very stable laterally. It is characterized by **low angle of attack and high airspeed**

A spiral dive is not a type of spin because neither wing is stalled. In a spiral dive, the airplane will respond conventionally to the pilot's inputs to the flight controls.

For example, a large finned airplane with **no dihedral**. In this case when the airplane is in a bank and side-slipping, the side force tends to turn the plane into the relative wind. The outer wing travels faster, generates more lift, and the airplane will roll to still a higher bank angle. No lateral stability is present to negate this roll. The bank angle increases and the airplane continues to turn into the sideslip in an ever-tightening spiral.