Subject Code & Name: **19AST302 FLIGHT DYNAMICS** Date:**15.11.2023**

DAY:**32** TOPIC: ***RUDDERREQUIREMENTS***

The rudder plays different roles for different phases of flight in various aircraft. Six major functions of a rudder are:

1) Crosswind landing,

2) Directional control for balancing asymmetric thrust on multi-engine aircraft,

3) Turn coordination,

4) Spin recovery,

5) Adverse yaw, and

6) Glide slope adjustment for a glider.

Table 12.21 tabulates these cases that impose different requirements for various aircraft. In this section, these design requirements are introduced, formulated and a technique to design the rudder to satisfy these requirements is developed.

Among these functions, one of them is usually the most critical one depending upon the aircraft mission and configuration. From six duties of rudder mentioned above, the first three ones are simple but last three ones are more important. For instance, multi-engine aircraft often have directional trim in case of asymmetric thrust as the most critical case for a rudder. Single engine aircraft often have the maximum crosswind landing as the critical condition. In a spinnable aircraft, the spin recovery imposes the most critical rudder design requirement. The design of rudder is performed with regard to the most critical role of rudder. In some aircraft, spin recovery is the critical one, but in some, asymmetric power condition is critical role of rudder. In un-spinnable normal aircraft, cross wind landing is often the most critical condition for rudder by which its design proceed. Therefore, one of the first tasks of the rudder designer is to identify the most crucial case for rudder to function within aircraft flight envelope.

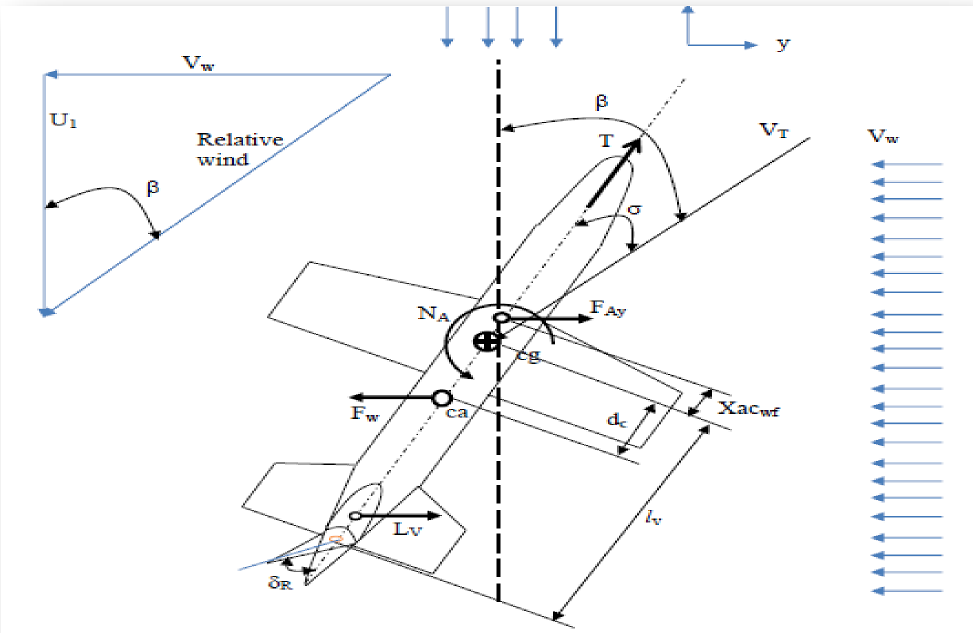
Asymmetric Thrust

In a multi-engine aircraft; when al engines are not located along fuselage center line; directional trim must be achieved when the critical engine(s) fails (e.g. one or more engines are inoperative). The critical engine failure must represent the most critical mode of powerplant failure with respect to controlability expected in service. Is such a case, operative engine(s) creates an undesirable yawing moment that must be nulified by the rudder. This design requirement is not applicable to a single engine aircraft where the engine thrust is aligned with fuselage centreline (in fact, when thrust-line is passing through the aircraft center of gravity). The same is true for a twin engine aircraft when both engines are placed along fuselage center-line (such as Voyager aircraft where one prop-engine is located at the fuselage nose and the other one is at the fuselage rear section). The critical asymmetric power/thrust condition frequently occurs when al engines of one side of the aircraft fail at low speeds. The rudder must be powerful enough to overcome the yawing moment produced by the asymmetric thrust arrangement.

Crosswind Landing

One of the most important functions of a rudder in al types of aircraft is to maintain safe landing while a crosswind is blowing. When a cross wind blows during landing operation; and if the pilot does not react, the aircraft wil exit out of the runway. The pilot is required to employ a special technique to maintain alignment with the runway during cross-wind landing. In general, the final approach under crosswind conditions may be conducted in two ways:

1. with wings-level (i.e., applying a drift correction in order to track the runway center line, this type of approach is called a crabbing;
2. with a steady sideslip (i.e., with the aircraft fuselage aligned with the runway centre line, using a combination of into-wind aileron and opposite rudder to correct the drift). Most airlines recommend the first technique.



Forces and angles in crosswind crabbed landing

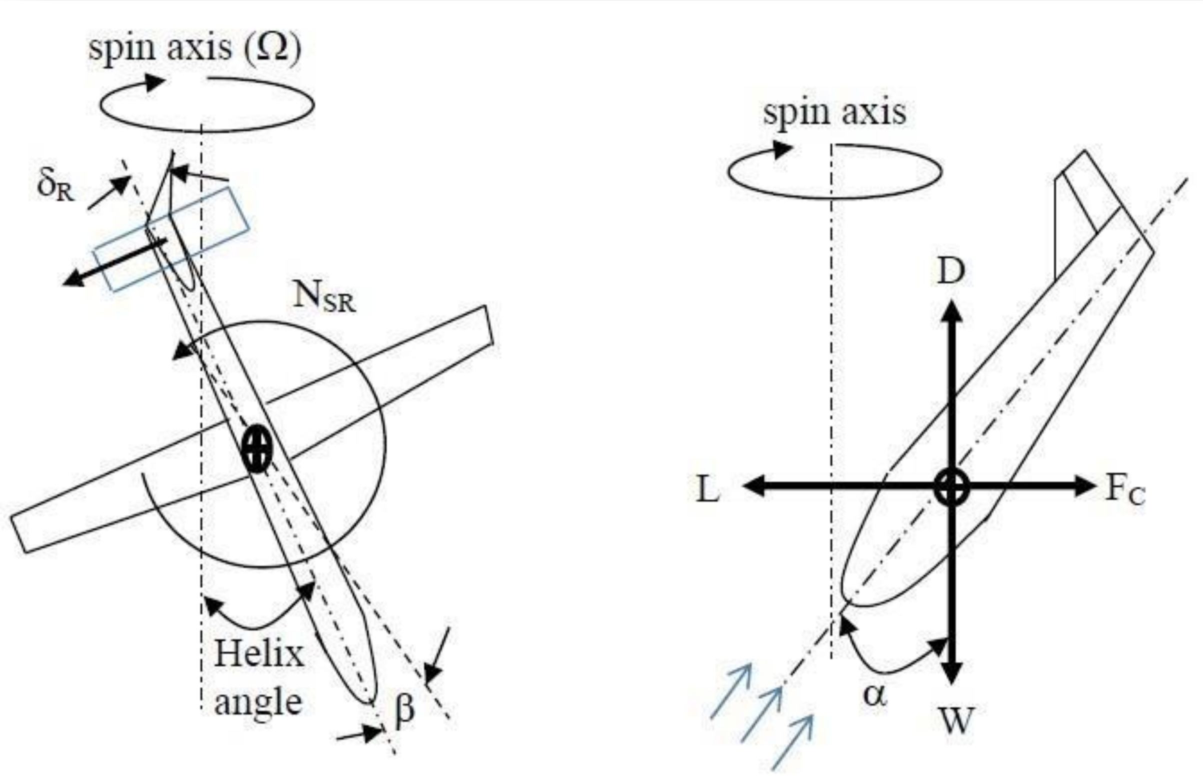
During the crosswind landing, rudder is applied to align the aircraft with the runway heading.

The rudder must be powerful enough to permit the pilot to trim for the specified cross-winds. The reason why aircraft deviate toward cross wind (and then changing the right direction of landing) is directional (weathercock) stability of aircraft. In such situation, the rudder produces a sideslip angle to maintain alignment with the runway. In this section, the first technique is addressed and governing equations are developed. When touching down with some crab angle on a dry runway, the aircraft automatically realigns with the direction of travel down the runway. However, if prevailing runway conditions and crosswind component are considered inadequate for a safe landing, the pilot may request the assignment of a more favorable runway.

Spin Recovery

One of the most important roles of a rudder in majority of airplanes is spin recovery. The most significant instrument to recover aircraft from a spin is a powerful rudder. Spin is a self- sustaining (auto-rotational) spiral motion of an airplane about vertical (z) axis, during which the mean angle of attack of the wings is beyond the stall. Almost since man first flew,

Spinning has caused many fatal accidents, so that most accidents were due to spin. During years 1965 to 1972, US Navy has lost an average of 2 aircraft per month and total of 169 aircraft due to spin, the list of which is headed by 44 fighter aircraft F-4s (Phantom). This statistics show the crucial role of the rudder in a spin. Spin is a high angle of attack/low airspeed situation; the airspeed will be hovering somewhere down in the stall area. Spin has two particular specifications:
Fast rotation around vertical axis,
Fully stalled wing. Spin is usually starts after wing stalls.



One of the reasons why aircraft enter into spin is that inboard of the wing stalls before outboard of the wing, in other word, lift distribution over the wing is not elliptic. Spin is recovered by a procedure which al control surfaces (elevator, aileron, and rudder) contribute; particularly the rudder in an apparently unnatural way. The rudder is the most significant element is spin recovery to stop rotation. The primary control for spin recovery in many airplanes is a powerful rudder. The rudder must be powerful enough to oppose the spin rotation in the first place. A spin follows departures in rol, yaw and pitch from the condition of trim between the predominantly pro-spin moment due to the wings and the generally anti- spin moments due to other parts of the aircraft. If spin is not recovered, aircraft will eventually crash. The criterion for rudder design in a spinnable aircraft may be spin recovery. Acrobatic and fighter airplanes are usually spendable, but there are some airplanes such as some transport aircraft that are spin-proof or un-spinnable. In un-spinnable aircraft, spin recovery is not a criterion for design of rudder, i.e. Rudder does not have to recover aircraft from spin.