J – 12, Q – 6c

Commuter aircraft

Q. why do commuter aircraft usually have unpressurised cabin?

A. Commuter aircraft are civil aircraft typically used for short-range transportation and mostly used by regional airlines or short-range charter airlines.

Most commuters are powered by turboprop engines and typically carry 20-70 passengers over distances less than 1,200 nm.

In the United States, Federal Air Regulations require that unpressurized aircraft flying above 12,500 feet be equipped with oxygen for the flight crew, and they must be equipped with oxygen for everyone above 15,000 feet.

Most of the commuter aircrafts fly below 15000 ft so they have unpressurised cabins.

Twin -Tails

J – 12, Q – 3b

Q. why do we see twin-vertical tails on high performance fighter aircrafts?

A. A twin tail is an aircraft with a set of two stabilizers mounted vertically on the tail assembly. Aircraft with this configuration are more stable and easier to control. The twin tail design was especially popular during the Second World War and continues to be used in the production of a number of aircraft today, including both small and large planes. This design is easy to identify at a glance, as the configuration tends to stand out.

On a twin tail aircraft, there is a large horizontal stabilizer, with smaller vertical stabilizers mounted at either end in a distinctive H shape. These stabilizers act as rudders, keeping the aircraft level and allowing the pilot to control the dynamics of the plane while it is in flight. Unlike single tail aircraft, they can be smaller, as the plane is not relying on one rudder for stability. Having two will usually increase rudder surface area over that of a single tail, providing a higher degree of control.

In a variation on the twin tail design, a plane can have two fuselages connected to a single horizontal stabilizer, with twin tails at the ends to keep the plane stable. This design is commonly seen in military aircraft and is referred to as a double tail or twin boom tail. Engineers working on designs for new aircraft can consider the applications the plane is being designed for and select the best body shape and tail assembly for the situation.

One advantage to the twin tail is the ability to control the plane even if one tail becomes compromised. For military planes, this is important, as enemy aircraft, as well as anti-aircraft guns may aim for the tail with the goal of destabilizing the plane so the pilot can no longer control it, forcing it to the ground.

The small tails are harder targets to hit accurately, and if a hit is landed on one of the rudders, the other will still operate. The plane will be harder to control, but it will not be completely destabilized and the pilot has a chance of reaching safety.

The lower profile of this configuration can also be useful when arranging planes in hangars, as they do not need as much clearance. Additionally, in the case of military planes, tail gunners have more visibility and range when they do not need to work around a very prominent single tail. These advantages can all be design considerations when developing new planes.

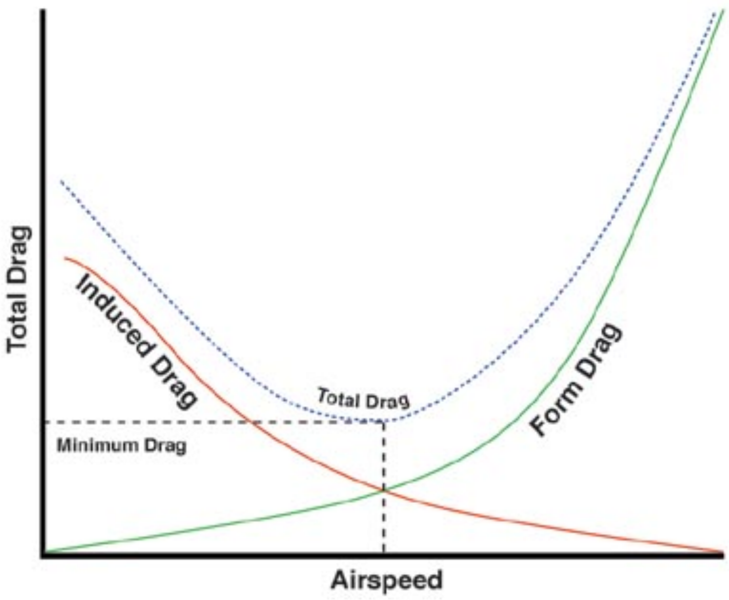
Profile drag and Induced drag

J – 12, Q – 3c

Q. Distinguish between profile drag and induced drag

A. Profile or Parasitic drag is drag caused by moving a solid object through a fluid medium (in the case of aerodynamics, more specifically, a gaseous medium). Parasitic drag is made up of many components, the most prominent being **form drag**. **Skin friction** and **interference drag** are also major components of parasitic drag.

In aviation, induced drag tends to be greater at lower speeds because a high angle of attack is required to maintain lift, creating more drag. However, as speed increases the induced drag becomes much less, but parasitic drag increases because the fluid is flowing faster around protruding objects increasing friction or drag.



At even higher transonic and supersonic speeds, wave drag enters the picture. Each of these forms of drag changes in proportion to the others based on speed. The combined overall drag curve therefore shows a minimum at some airspeed - an aircraft flying at this speed will be at or close to its optimal efficiency. Pilots will use this speed to maximize the gliding range in case of an engine failure.

However, to maximize the gliding endurance, the aircraft's speed would have to be at the point of minimum power, which occurs at lower speeds than minimum drag. At the point of minimum drag, $C_{D,o}$ (drag coefficient of aircraft when lift equals zero) is equal to $C_{D,i}$ (induced drag coefficient, or coefficient of drag created by lift). At the point of minimum power, $C_{D,o}$ is equal to one third times $C_{D,i}$. This can be proven by deriving the following equations:

For a low speed aircraft transonic or wave drags don’t exist still at cruise i.e., low subsonic speed, profile drag will be greater than the induced drag.

$$F_{drag} = \frac{1}{2}\rho V^2 A_s C_D$$

and

$$C_D = C_{D,o} + C_{D,i}$$

where

$$C_{D,i} = K C_L^2$$

Bypass ratio

J – 12, Q – 3d

Q. Explain the term Bypass ratio of an engine. For which applications is a low bypass ratio engine suitable?

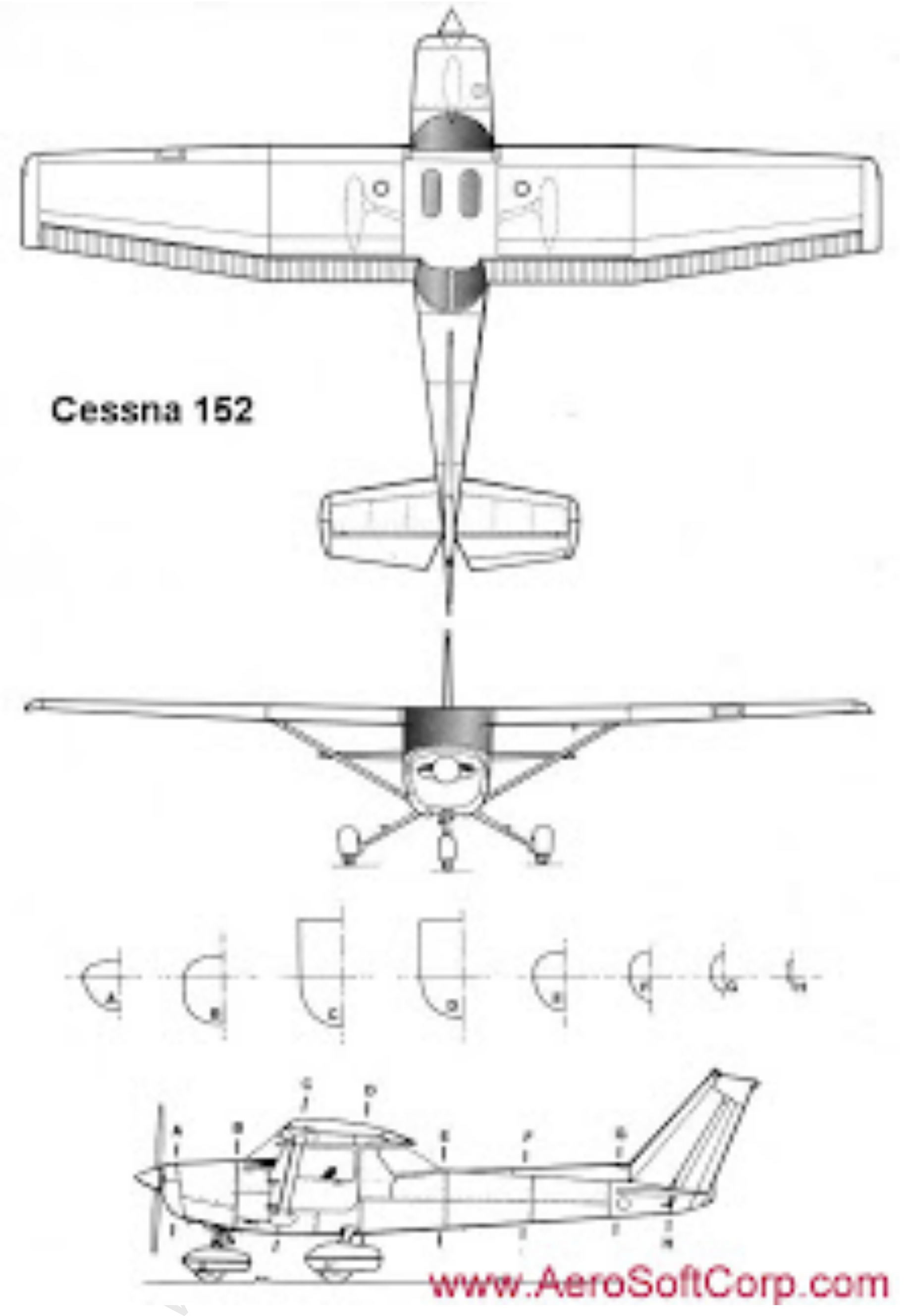
A. The term **bypass ratio (BPR)** relates to the design of turbofan engines, commonly used in aviation. It is defined as the ratio between the mass flow rate of air drawn through a fan disk which bypasses the engine core (un-combusted air), to the mass flow rate passing through the engine core which is involved in combustion to produce mechanical energy. For example, with a 10:1 bypass ratio, for every 1 kg of air passing through the combustion chamber, 10 kg of air passes *around* the combustion chamber through the ducted fan alone.

Low bypass ratios tend to be favored for military combat aircraft as a compromise between improved fuel economy and the requirements of combat, which values higher power-to-weight ratios, supersonic performance, and the ability to use afterburners which are more compatible with low bypass engines. A good example of the differences between a pure jet engine and a low-bypass turbofan may be seen in the Spey turbofan used in the F-4 Phantom.

In a **high-bypass** design, the vast majority of the thrust is derived from the ducted fan, rather than from combustion gases expanding in a nozzle. A high bypass ratio provides a lower thrust specific fuel consumption (grams/sec fuel per unit of thrust in kN using SI units) for reasons explained below, especially at zero velocity (at takeoff) and at the cruise speed of most commercial jet aircraft. They are by far the dominant type for all commercial passenger aircraft and both civilian and military jet transports. Lower exhaust velocities also figure strongly in lower noise output which is a decided advantage over earlier low or zero bypass designs.

Nose Wheel Landing Gear

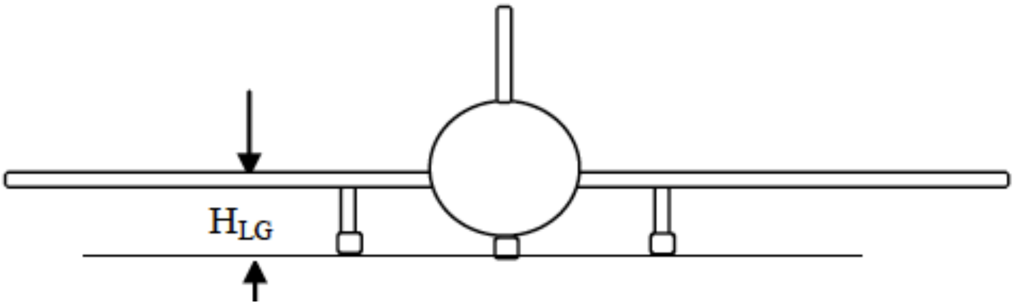
J -12, Q – 7a



At this point, the landing gear configuration is selected and retraction configuration is decided. Now, the designer needs to perform mathematical calculations to determine few parameters such as height, wheel base, wheel track, and the distance between main gear and aircraft center of gravity. These parameters are interrelated through geometrical relations and several mathematical principles.

Landing Gear Height

Landing gear height (H_{LG}) is defined as the distance between the ground and the conjunction between main gear strut and the aircraft structure.

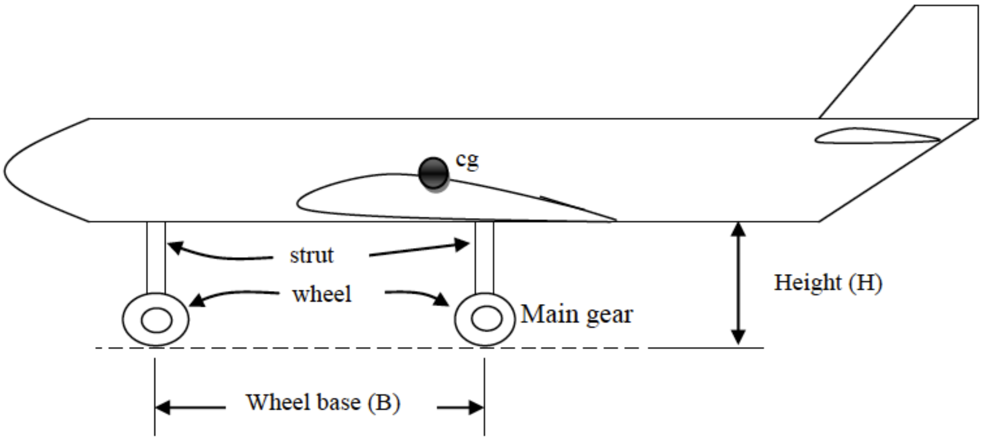


There are mainly five design requirements in which landing gear height play an important role. They are:

1. Landing gear height provides aircraft clearance during taxi.
2. Landing gear height provides rear fuselage clearance during take-off rotation.
3. Landing gear height contributes to tip-back prevention.
4. Landing gear height contributes to overturn prevention.
5. Landing gear height satisfies loading and unloading requirements.

Wheel Base

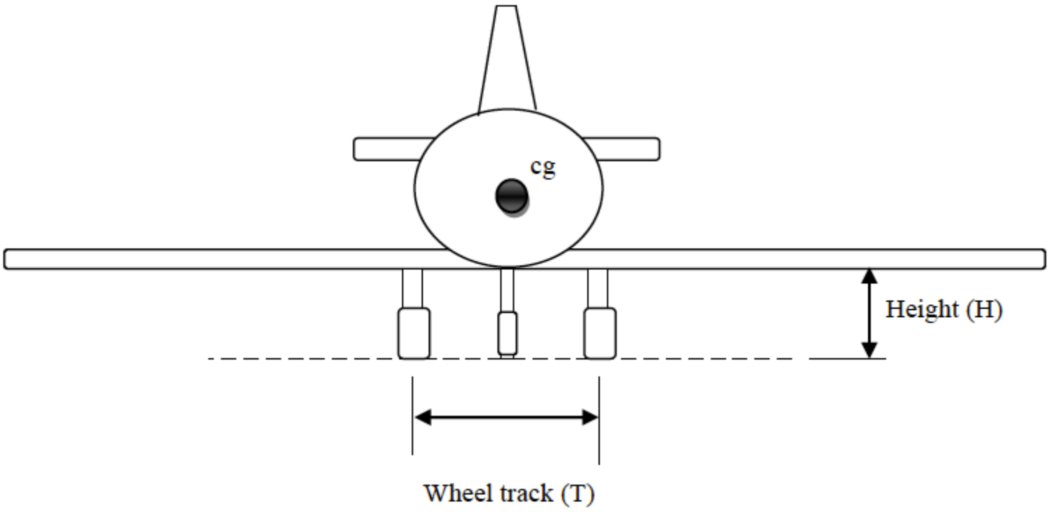
Wheel base (B) plays an important role on the load distribution between primary (i.e. main) gear and secondary (e.g. nose, or tail) gear. This parameter also influences the ground controllability and ground stability.



Thus, the wheel base must be carefully determined and an optimum value needs to be calculated to ensure it meets all relevant design requirements.

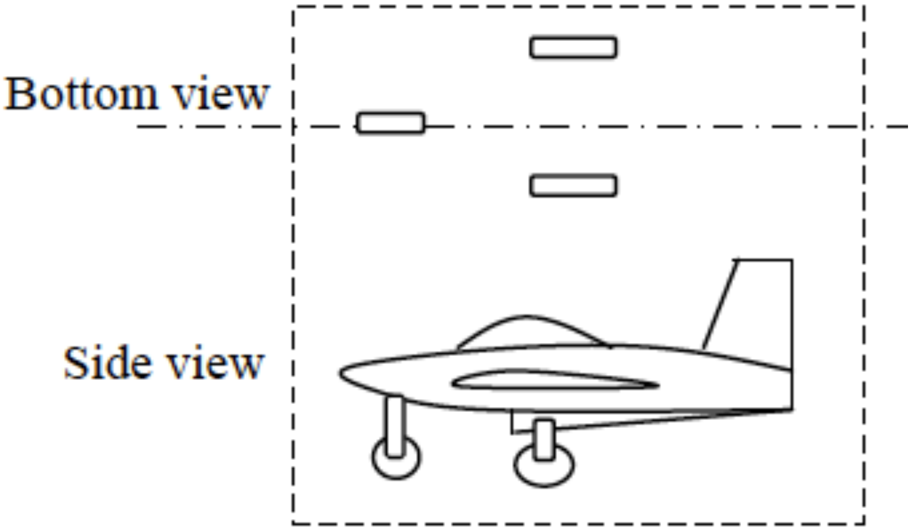
Wheel Track

Wheel track (T) is defined as the distance between the most left and the most right gears (when looking at front-view) and is measured at the ground. Three main design requirements which drive the magnitude of this parameter are: 1. Ground lateral control, 2. Ground lateral stability, and 3. Structural integrity. The wheel track of the main wheel should be arranged so that the aircraft cannot roll over too easily due to wind or during a ground turn.



Overturn Angles Requirement

One of the influencing requirements on the design of landing gear is the overturn angle requirement. This requirement sets minimum and maximum limits for the wheel track. In general, there are two disturbing moments which are able to overturn an aircraft: 1. Centrifugal force in a ground turn, 2. Cross wind force. The first force is addressed in ground controllability requirement, while the second one is examined in the ground stability requirement.



Practical Steps for Wing Airfoil Section Selection

J -12, Q – 7b

A. The wing designer is planning to select the best airfoil from the list. The steps are as follows:

1. Determine the average aircraft weight (W_{avg}) in cruising flight:

$$W_{avg} = \frac{1}{2}\left(W_i + W_f\right) \tag{5.9}$$

where W_i is the initial aircraft weight at the beginning of cruise and W_f is the final aircraft weight at the end of cruise.

2. Calculate the aircraft ideal cruise lift coefficient (C_{L_C}). In a cruising flight, the aircraft weight is equal to the lift force (equation 5.1), so:

$$C_{L_c} = \frac{2W_{ave}}{\rho V_c^2 S} \tag{5.10}$$

where V_c is the aircraft cruise speed, ρ is the air density at cruising altitude, and S is the wing planform area.

3. Calculate the wing cruise lift coefficient ($C_{L_{C_w}}$). Basically, the wing is solely responsible for the generation of the lift. However, other aircraft components also contribute to the total lift; negatively, or positively; sometimes, as much as 20 percent. Thus the relation between aircraft cruise lift coefficient and wing cruise lift coefficient is a function of aircraft configuration. The contribution of fuselage, tail and other components will determine the wing contribution to aircraft lift coefficient. If you are at the preliminary design phase and the geometry of other components have not been determined yet, the following approximate relationship is recommended.

$$C_{L_{C_w}} = \frac{C_{L_C}}{0.95} \tag{5.11}$$

In the later design phases; when other components are designed; this relationship must be clarified. A CFD software package is a reliable tool to determine this relationship.

4. Calculate the wing airfoil ideal lift coefficient (C_{l_i}). The wing is a three-dimensional body, while an airfoil is a two-dimensional section. If the wing chord is constant, with no sweep angle, no dihedral, and the wing span is assumed to be infinity; theoretically; the wing lift coefficient would be the same as wing airfoil lift coefficient. However, at this moment, the wing has not been designed yet, we have to resort to an approximate relationship. In reality, the span is limited, and in most cases, wing has sweep angle, and non-constant chord, so the wing lift coefficient will be slightly less than airfoil lift

coefficient. For this purpose, the following approximate equation[8] is recommended at this moment:

$$C_{l_i} = \frac{C_{L_{C_w}}}{0.9} \tag{5.12}$$

In the later design phases, by using aerodynamic theories and tools, this approximate relation must be modified to include the wing geometry to the required airfoil ideal coefficient.

5. Calculate the aircraft maximum lift coefficient ($C_{L_{max}}$):

$$C_{L_{max}} = \frac{2W_{TO}}{\rho_o V_s^2 S} \tag{5.13}$$

where V_s is the aircraft stall speed, ρ_o is the air density at sea level, and W_{TO} is the aircraft maximum take-off weight.

6. Calculate the wing maximum lift coefficient ($C_{L_{max_w}}$). With the same logic that was described in step 3, the following relationship is recommended.

$$C_{L_{max_w}} = \frac{C_{L_{max}}}{0.95} \tag{5.14}$$

7. Calculate the wing airfoil gross maximum lift coefficient ($C_{l_{max_{gross}}}$).

$$C_{l_{max_{gross}}} = \frac{C_{L_{max_w}}}{0.9} \tag{5.15}$$

where the wing airfoil "*gross*" maximum lift coefficient is the airfoil maximum lift coefficient in which the effect of high lift device (e.g. flap) is included.

8. Select/Design the high lift device (type, geometry, and maximum deflection). This step will be discussed in details in section 5.12.

9. Determine the high lift device (HLD) contribution to the wing maximum lift coefficient ($\Delta C_{l_{HLD}}$). This step will also be discussed in details in section 5.12.

10. Calculate the wing airfoil "*net*" maximum lift coefficient ($C_{l_{max}}$)

$$C_{l_{max}} = C_{l_{max_{gross}}} - \Delta C_{l_{HLD}} \tag{5.16}$$

11. Identify airfoil section alternatives that deliver the desired C_{li} (step 4) and C_{lmax} (step 10). This is a very essential step. Figure 5.23 shows a collection of C_{li} and C_{lmax} for several NACA airfoil sections in just one graph. The horizontal axis represents the airfoil ideal lift coefficient while the vertical axis the airfoil maximum lift coefficient. Every black circle represents one NACA airfoil section. For C_{li} and C_{lmax} of other airfoil sections, refer to [4] and [3]. If there is no airfoil section that delivers the desired C_{li} and C_{lmax}, select the airfoil section that is nearest to the design point (desired C_{li} and C_{lmax}).
12. If the wing is designed for a high subsonic passenger aircraft, select the thinnest airfoil (the lowest $(t/c)_{max}$). The reason is to reduce the critical Mach number (M_{cr}) and drag-divergent[9] Mach number (M_{dd}). This allow the aircraft fly closer to Mach one before the drag rise is encountered. In general, a thinner airfoil will have a higher M_{cr} than a thicker airfoil [6]. Figure 5.24 shows the typical variation of the wing zero-lift and wave drag coefficient versus Mach number for four wings with airfoil thickness ratio as a parameter. As noted, the M_{dd} of the wing with 9 percent thickness-to-chord ratio occurs at the value of about 0.88. By reducing the wing $(t/c)_{max}$ to 6 and 4 percent, the magnitude of the drag rise is progressively reduced, and the value of M_{dd} is increased, moving closer to Mach one.

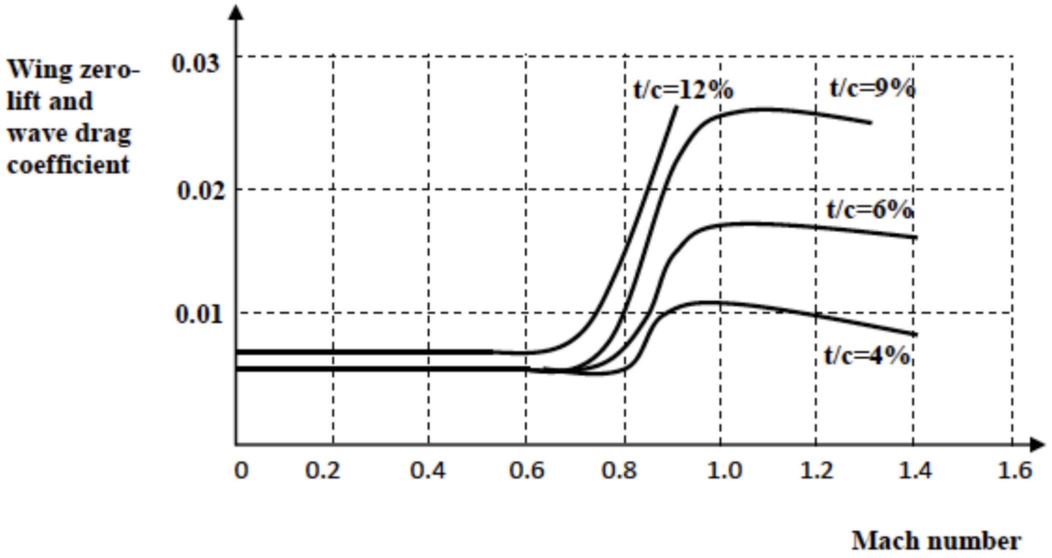


Figure 5.24. Variation of wing zero-lift and wave drag coefficient versus Mach number for various airfoil thickness ratio.

Design objectives	Weight	Airfoil 1	Airfoil 2	Airfoil 3	Airfoil 4	Airfoil 5
C_{dmin}	25%					
C_{mo}	15%					
α_s	15					
α_o	10					
$(C_l/C_d)_{max}$	10%					

$C_{l\alpha}$	5%					
Stall quality	20%					
Summation	100%	64	76	93	68	68

Table 5.5. A sample table to compare the features of five airfoil sections

13. Among several acceptable alternatives, select the optimum airfoil section by using a comparison table. A typical comparison table which includes a typical weight for each design requirement is shown in table 5.5. Reference [1] is a rich resource for the systematic procedure of the selection technique and table construction.