Mass & balance

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At the first let me ask a question

Why did human want to fly?

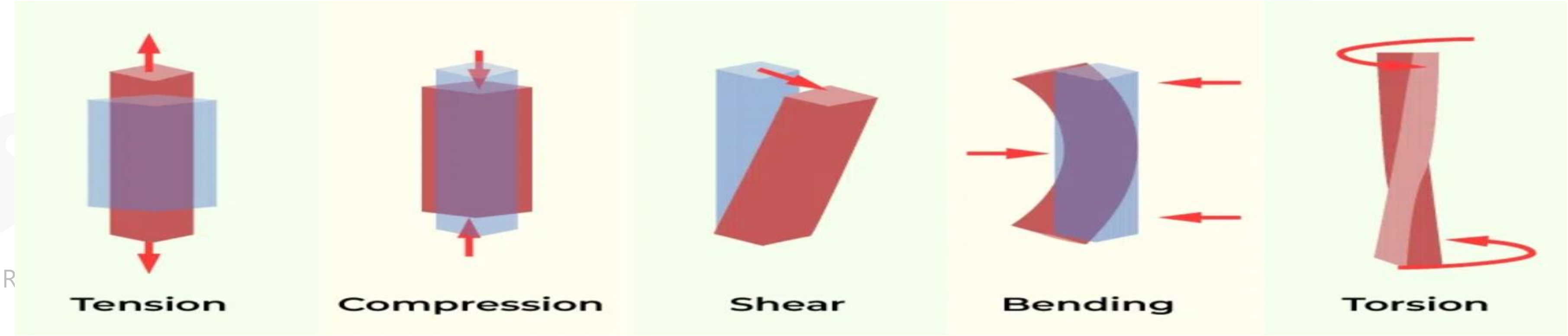
It is the responsibility of the pilot in command to ensure that this requirement is met. It is important to note that Mass and Balance is also commonly referred to as Weight and Balance.

Limitations

- Limitations on mass are set to ensure adequate margins of strength and performance.
- Limitations on CG position are set to ensure adequate stability and control of the aircraft in flight.

Aircraft Mass and Structural Stress

The four forces of lift, weight, thrust, and drag acting on an aircraft all induce stress into the airframe structural members in the form of tension, compression, torsion, and bending. The structure may, at the same time of absorbing these stresses, be subject to extreme temperature



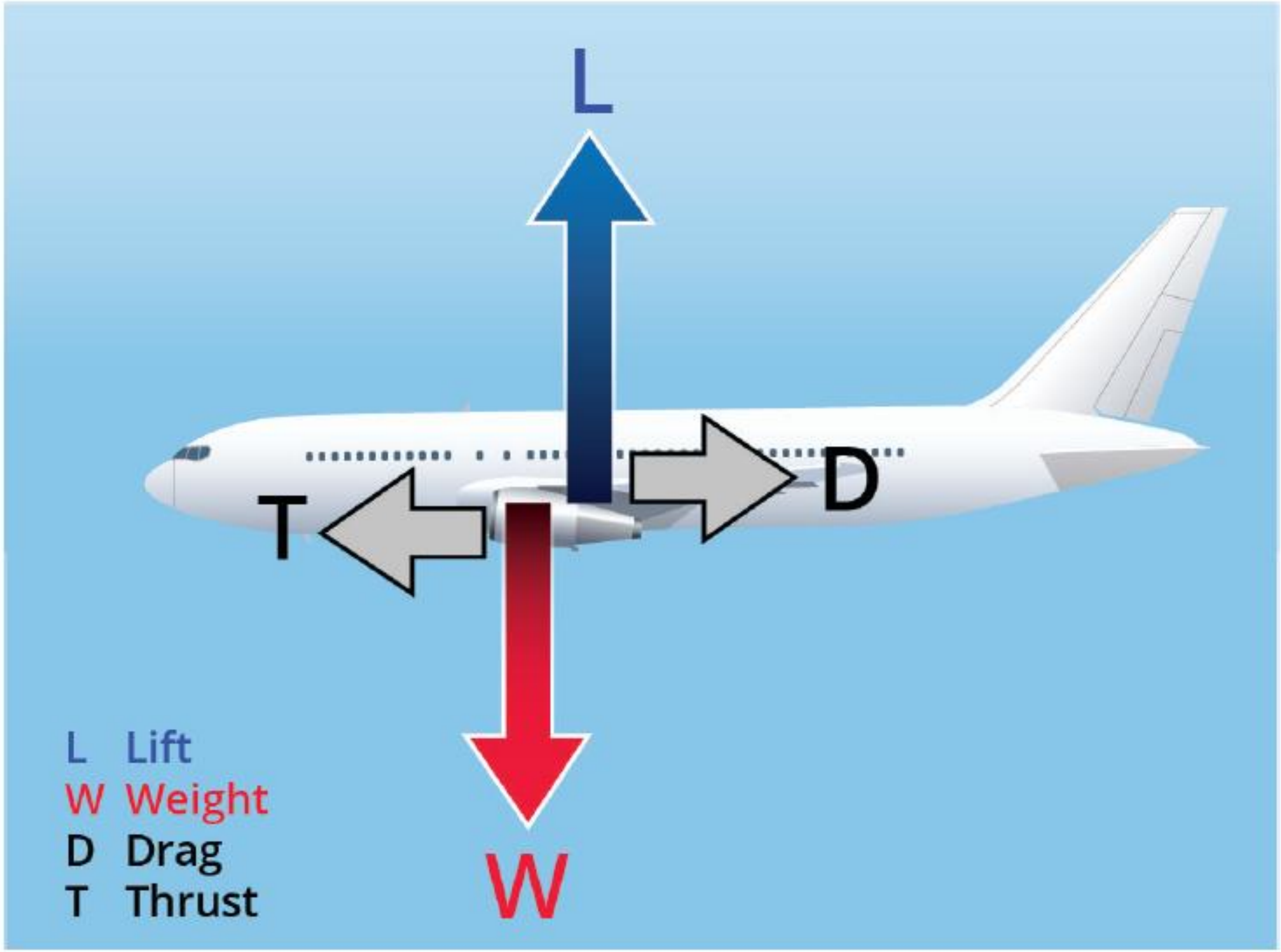


Figure 1.1 Four forces of flight

An aeroplane's primary function is to lift mass into the air, transport that mass, and then land without damage. Clearly, the greater the mass to be lifted, the greater the load bearing on the aircraft structure will be. Furthermore, overloading the aeroplane will induce additional fatigue and decrease performance. For the purposes of cost efficiency, it is important to maximise the mass transported by the aeroplane while respecting the aircraft's loading limitations.

The manufacturer is responsible for the aircraft's structure and determines the limitations that the aircraft will be subject to, both on the ground and in flight. In doing so, it guarantees the integrity and longevity of the aircraft's service life.

The limits include:

- Maximum taxi mass (MTM)
- Maximum zero fuel mass (MZFM)
- Maximum structural takeoff mass (MSTOM)
- Maximum structural landing mass (MSLM)

These values must never be exceeded in normal operation.

Increasing age, inappropriate use, hostile environmental and climatic conditions are all factors that induce stress and fatigue into the aircraft's structure. However, weight is the principal stress factor for inducing fatigue into aircraft structure.

Stress and temperature factors gradually fatigue the structure as time progresses. Fatigue, in this sense of the word, is a permanent loss of the physical properties (strength, durability, hardness, etc.) of the materials comprising the structure. Fatigue, if left undetected or unattended, will eventually cause the structure to fail altogether, possibly with catastrophic and/or fatal consequences.

Fatigue is cumulative and non-reversible and the higher the fatigue level the greater the risk of premature structural failure. Structure that is inadvertently subject to additional fatigue may fail earlier than predicted or expected.

The aircraft designer must, for each individual part of the structure, determine the frequency of application of the stress producing loads and, together with the temperature factors, determine the types of stress involved. Based on this data, a design limit load (DLL) is calculated for each member and for the complete structure. The DLL is the maximum load that can be applied to the structure repeatedly during normal operations without inducing excessive fatigue. Consequently, the pilot must never deliberately exceed this value.

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As a safeguard, the aviation authorities impose a factor of safety of 50% to the DLL to produce a design ultimate load (DUL). The DUL is the minimum load the structure must be able to absorb in an emergency (heavier than normal landing or flight in exceptional gusty wind conditions) without collapsing. In order to keep weight to a minimum, the aircraft's structure is manufactured from materials that are just capable of absorbing the DUL.

Structure, subject to loads in excess of the DUL, is likely to suffer permanent damage and may even collapse altogether.

Importance with Regard to Performance

Mass also has pronounced effects on the aircraft's performance, handling and aerodynamic properties. Aircraft have a limited amount of thrust. Exceeding mass limitations could result in the thrust available not being sufficient for the thrust required.

Effects of Increasing Aeroplane Mass

- Performance is reduced.
- Takeoff and landing distances will increase.
- V_1 decision speed, V_R rotation speed, V_2 takeoff safety speed, V_{MU}, and the stopping distance will increase.
- The stalling speed will increase and maximum speed will reduce.
- The climb gradient, rate of climb and ceiling height will reduce.
- The rate of descent will increase.
- Drag and fuel consumption will increase.
- Range and endurance will reduce.
- Wing root stresses will increase.
- Manoeuvrability will reduce. The aircraft will become less responsive to control inputs and more difficult to fly.
- Wing root stresses and undercarriage loads will increase as well as tyre and brake will wear.

With the above effects on aircraft's performance and an increase in mass, two more limitations are found in addition to the structural limitations. These performance limitations must also never be exceeded in normal operation.

- Performance limited takeoff mass (PLTOM)
- Performance limited landing mass (PLLM)

Centre of Gravity (CG) Limitations

Centre of Gravity (CG)

- The point that the total weight of the aircraft is said to act through
- The point of balance
- That part of the aircraft that follows the flight path
- The point that the aircraft manoeuvres about in the air
- The point that the three axes of the aircraft pass through.

The position of the centre of gravity (CG) determines how stable or how manoeuvrable the aircraft will be. Starting at the mid position of the fuselage, a CG moving towards the nose of the aircraft will progressively increase the stability, but at the same time, progressively reduce the manoeuvrability.

Similarly, a CG moving aft, towards the tail of the aircraft will increase the manoeuvrability but decrease the stability. Too much stability increases the flying control stick forces and the workload on the pilot trying to overcome them. Too much manoeuvrability makes the aircraft unstable and difficult to control.

To ensure the aircraft can be correctly controlled, while remaining stable, the manufacturer establishes the centre of gravity (CG) range. This is the maximum forward limitation and aft limitation for the CG position. The CG must remain within these limits both on the ground and during flight.

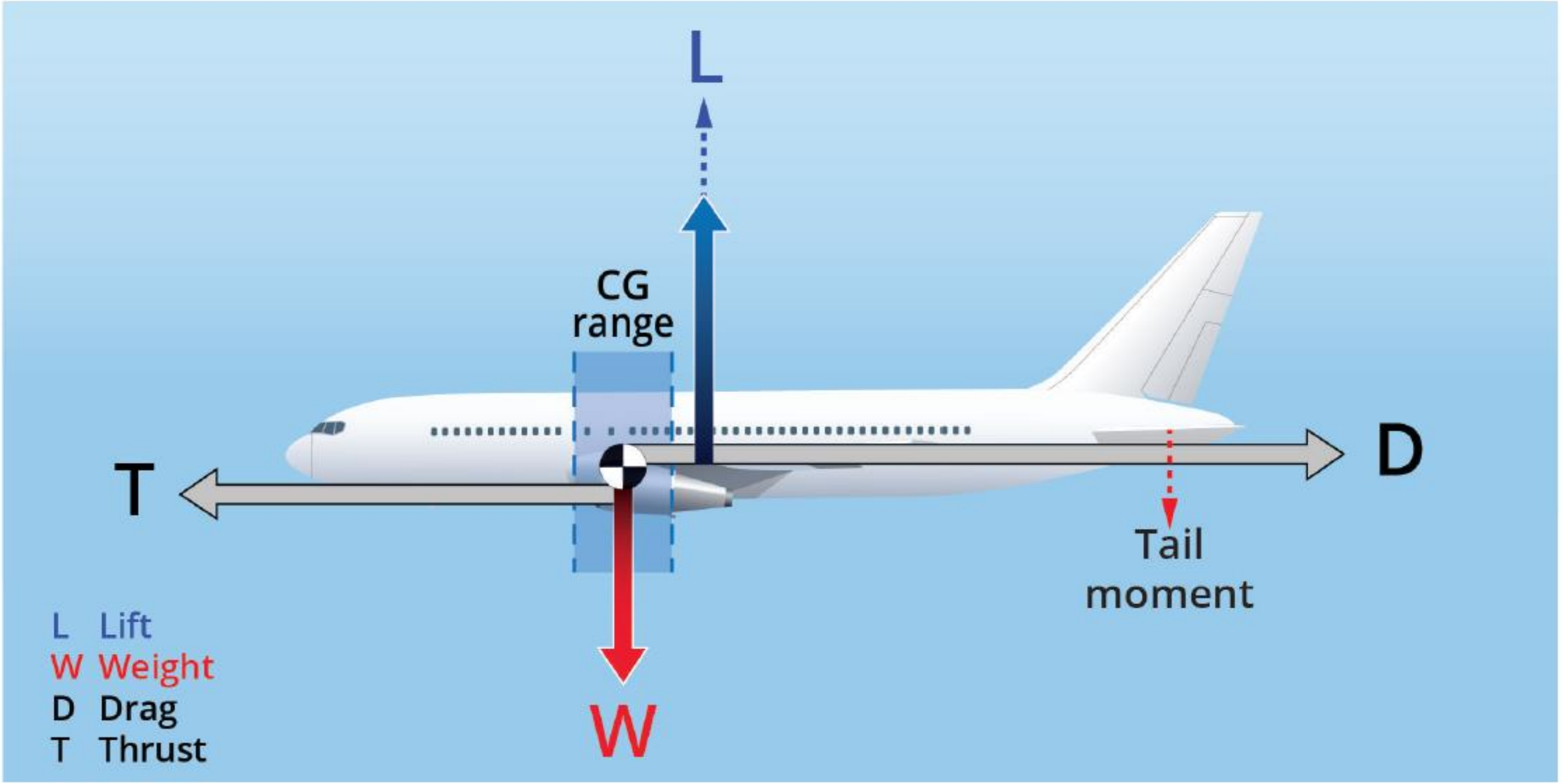


Figure 1.2 Centre of gravity range

CG in Front of Forward Limit

Drag increases, consequently fuel consumption increases, and both range and endurance decrease. To keep the nose of the aircraft from pitching downwards the tailplane must produce a balancing download – a bit like a seesaw. The resulting elevator deflection increases drag, which in turn increases fuel consumption and reduces range and endurance.

The longitudinal stability is increased, resulting in higher control column forces during manoeuvres with a corresponding increase in physical effort required to overcome them, leading to increased pilot fatigue.

The increase in tail-down force is equivalent to an increase in weight, consequently increasing the stall speed. An increase in stall speed has a significant effect on other performance aspects of the aircraft such as, takeoff and landing speeds will increase, the available speed range will reduce and the safety margin between low and high speed buffet will narrow.

The ability to pitch the aircraft's nose up or down will decrease because of the increased stability.

Takeoff speeds V_1, V_R, V_{MU} will increase. On the ground the aeroplane rotates about the main wheels and uses the elevators to raise the nose for takeoff. The CG, being ahead of the main wheels, produces a down force that the elevators, together with the speed of the airflow passing over them must overcome. The more forward the CG the greater the down force, and for a particular elevator deflection, the greater the speed of the airflow required. The aircraft must accelerate for longer to produce the airspeed required.

CG Behind Aft Limit

Longitudinal stability is reduced and, if the CG is too far aft, the aircraft will become very unstable. Stick forces in pitch will be light, leading to the possibility of over stressing the aircraft by applying excessive g.

Recovering from a spin may be more difficult as a flat spin is more likely to develop.

The optimum CG position for fuel efficiency is towards the aft limit. With the CG towards the aft limit, less downforce is required at the tailplane and therefore drag is reduced and range and endurance are increased.

Glide angle may be more difficult to sustain because of the tendency for the aircraft to pitch up.

Importance with Regard to Performance

CG ON FWD LIMIT		CG ON AFT LIMIT	
STABILITY	↑	STABILITY	↓
STICK FORCES	↑	STICK FORCES	↓
MANOEUVRABILITY	↓	MANOEUVRABILITY	↑
DRAG	↑	DRAG	↓
V_S (STALLING SPEED)	↑	V_S	↓
V_R (ROTATION SPEED)	↑	V_R	↓
V_1, V_2	↑	V_1, V_2	↓
V_{REF}	↑	V_{REF}	↓
FUEL CONSUMPTION	↑	FUEL CONSUMPTION	↓
RANGE	↓	RANGE	↑
ENDURANCE	↓	ENDURANCE	↑
CLIMB GRADIENT	↓	CLIMB GRADIENT	↑
RATE OF CLIMB	↓	RATE OF CLIMB	↑

↑ = increase

↓ = decrease

Mass Terms

Basic Empty Mass (BEM)

The basic empty mass (BEM) is the mass of an aeroplane including standard items such as:

- Unusable fuel and other unusable fluids
- Lubricating oil in engine, hydraulic fluid, and auxiliary units
- Fire extinguishers, pyrotechnics and emergency oxygen equipment
- Supplementary electronic equipment

All light aircraft use the BEM and its CG position as the foundation from which to calculate all relevant masses and CG positions.

Variable Load

The variable load is the mass of the operational items such as:

- Crew and crew baggage
- Catering and removable passenger service equipment
- Potable water and lavatory chemicals
- Food and beverages

Dry Operating Mass (DOM)

The dry operating mass (DOM) is the total mass of the aeroplane ready for a specific type of operation excluding usable fuel and traffic load. It is the BEM plus the variable load.

All large aircraft use the DOM as the foundation from which to calculate all relevant masses and CG positions. The load and trim sheet cannot be completed until the DOM and its CG position are known.

Operating Mass (OM)

The operating mass (OM) is the DOM plus takeoff fuel but excluding traffic load.

Takeoff Mass (TOM)

The takeoff mass (TOM) is the actual mass of the aeroplane at the start of the takeoff run, including everything and everyone contained within it. The TOM should never exceed the regulated takeoff mass.

Landing Mass (LM)

The landing mass (LM) is the actual mass of the aeroplane passing the threshold on landing, including everything and everyone contained within it. The LM should never exceed the regulated landing mass.

Ramp/Taxi Mass

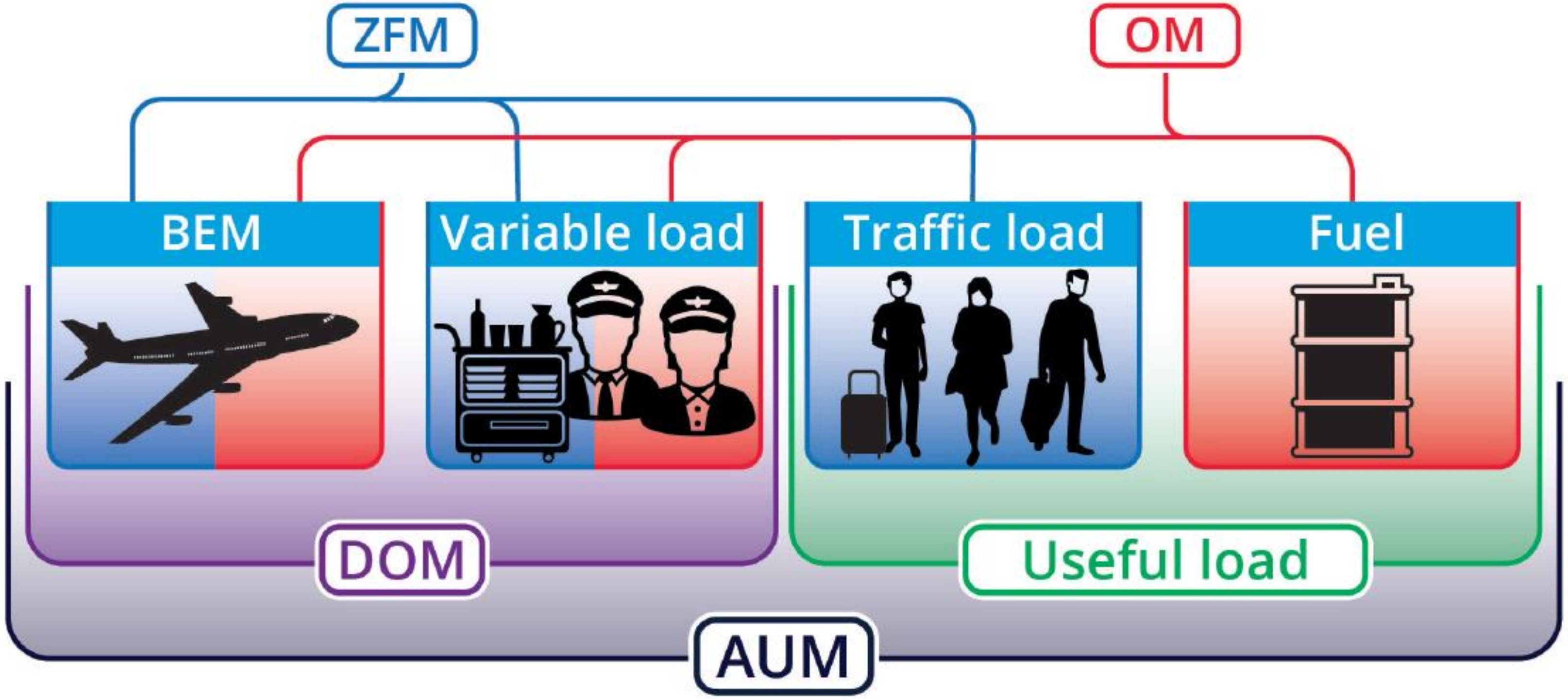
The ramp/taxi mass is the actual mass of the aeroplane at the start of the taxi (at departure from the loading gate) before engine start or any fuel has been used.

In-Flight Mass (Gross Mass)

The in-flight mass (gross mass) is the mass of the aeroplane at a particular time or condition, including everything and everyone contained within it. The term all-up mass is also used.

Zero Fuel Mass (ZFM)

The zero fuel mass (ZFM) is the dry operating mass (DOM) plus the mass of the traffic load. It is excluding all useable fuel.



Load Terms (Including Fuel Terms)

Payload/Traffic Load

Originally known as the payload, the traffic load is the revenue generating load. Passengers, baggage and cargo. This also should include any non-revenue load.

Useful Load

The useful load is the sum of the traffic load and the useable fuel.

Block Fuel

Block fuel or ramp fuel is the sum of fuel loaded for a sector. It consists of:

- Taxi fuel
- Trip fuel
- Contingency fuel
- Alternate fuel
- Final reserve fuel
- Additional fuel
- Extra fuel

Taxi Fuel

Taxi fuel is the amount of fuel required to start up, taxi, and hold (if necessary) before takeoff. It will also include any fuel required to operate pre-flight services, such as cabin conditioning, and may include use of the APU.

Takeoff Fuel (TOF)

The takeoff fuel (TOF) is the amount of fuel on board at commencement of the takeoff run. It is block fuel minus taxi fuel.

Trip Fuel

Trip fuel is the amount of fuel from the commencement of the takeoff run at the departure runway to completion of the landing at the destination runway.

This should include fuel:

- for the takeoff from the airfield elevation, the departure procedure (SID) and then to the top of climb (TOC) at the initial cruising level/altitude.
- from the TOC to top of descent (TOD), including any step climbs or descents.
- from TOD to the beginning of the approach, including expected arrival procedures (STARs).
- for approach and landing.

Reserve Fuel

Reserve fuel is further subdivided into:

- Contingency fuel
- Alternate fuel
- Final reserve
- Additional fuel

Contingency fuel: An operator must ensure that every flight carries sufficient fuel for the planned operation, and reserves to cover any replanning necessary for in-flight contingencies. A contingency is a chance occurrence or unforeseen event. Contingency fuel is carried to compensate for deviations from:

- The forecast meteorological conditions
- The planned routing and/or cruising levels/altitudes

Alternate fuel: This is simply the fuel required to fly from missed approach at the destination to the planned alternate. It should consider, probable routing, approach at the alternate and expected wind component, but it does not have its own allowance of contingency fuel. Contingency allowance is applied only to the trip fuel.

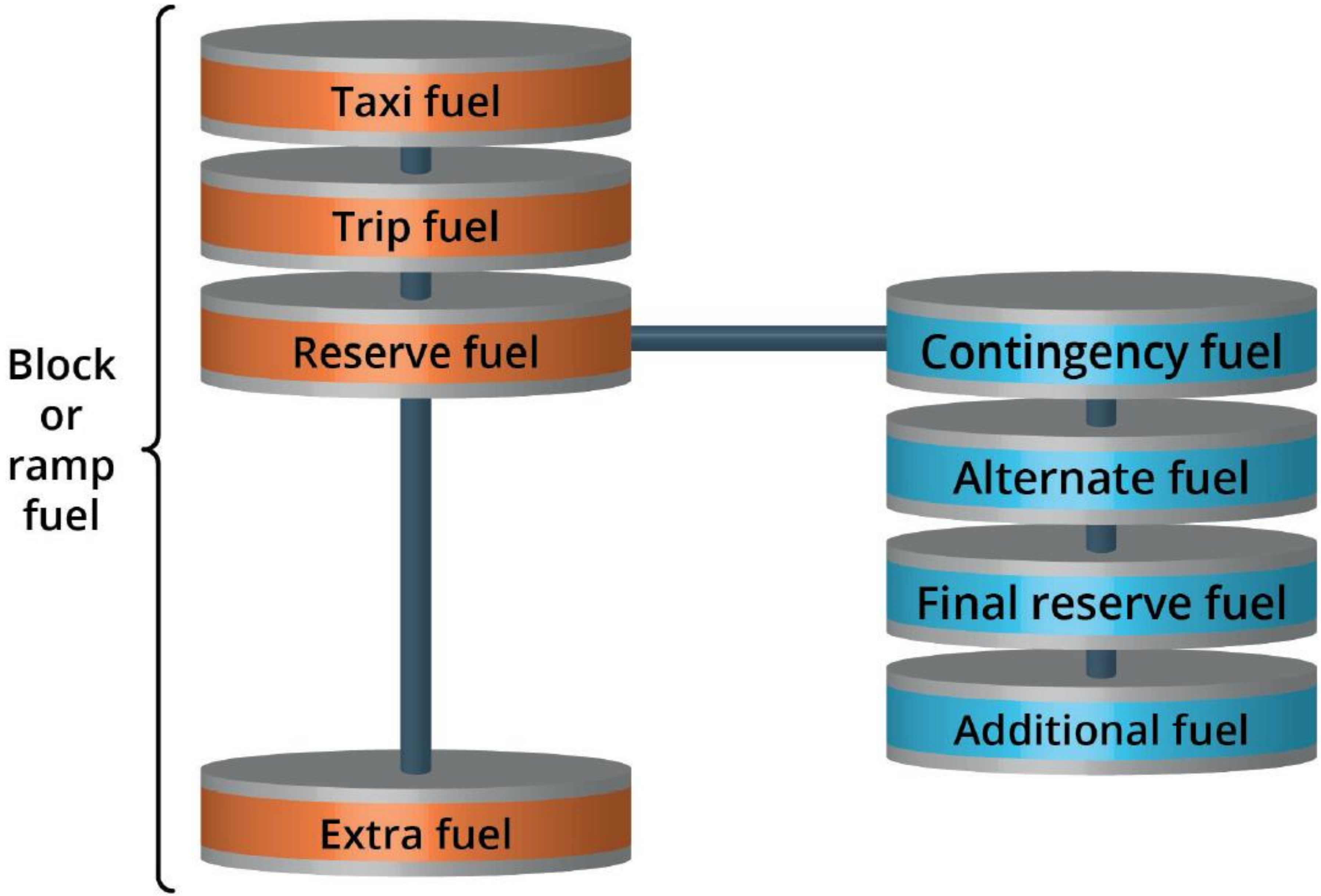
Final reserve fuel: If the aircraft are to fly from departure to destination, and use the contingency fuel en route, and then to conduct a missed approach at the destination and then fly to the alternate; the aircraft will have consumed all of the fuel on arrival. As a result of this a minimum landing fuel amount must be respected to ensure that the final reserve fuel is never used. This final reserve fuel consists of 30 min (jet/turboprop) at 1,500 ft above aerodrome level AAL in ISA conditions, or 45 min (piston engine aircraft) fuel consumption at endurance speed.

Additional fuel: Contingency, alternate and final reserve fuel cover most cases, provided that suitable diversions are available en route to the destination. Additional fuel may be needed if there is no alternate available at some isolated aerodromes. This is also known as the island holding situation. It could also be used to comply with minimum equipment list (MEL), configuration deviation list (CDL) restrictions or ETOPS.

Additional fuel should be sufficient to allow for an engine failure or depressurization. The aircraft is required to descend as necessary and proceed to an adequate alternate aerodrome and hold at 1,500 ft for 15 minutes above the aerodrome elevation in ISA conditions, and then complete an approach and landing.

Extra Fuel

Extra fuel is any fuel above the minima required by taxi, trip and reserve fuel. It can simply be because more has been uplifted than is required for the trip, so the surplus is defined as extra fuel. Usually, even when all the minima required by EASA fuel policy is fulfilled, the pilot in command decides that based on his judgement more fuel is required for the completion of the flight.


Block
or
ramp
fuel
Taxi fuel
Trip fuel
Reserve fuel
Extra fuel
Contingency fuel
Alternate fuel
Final reserve fuel
Additional fuel

Example 1

Ramp mass 59,800 kg – taxi fuel 260 kg = Takeoff mass 59,540 kg

Zero fuel mass 4,187 lb + takeoff fuel 540 lb = Takeoff mass 4,727 lb

Takeoff mass 31,285 kg – trip fuel 4,250 kg = Landing mass 27,035 kg

Example 2

It is also required to understand the terminology of particular mass items. Calculations using the terminology are required to be completed.

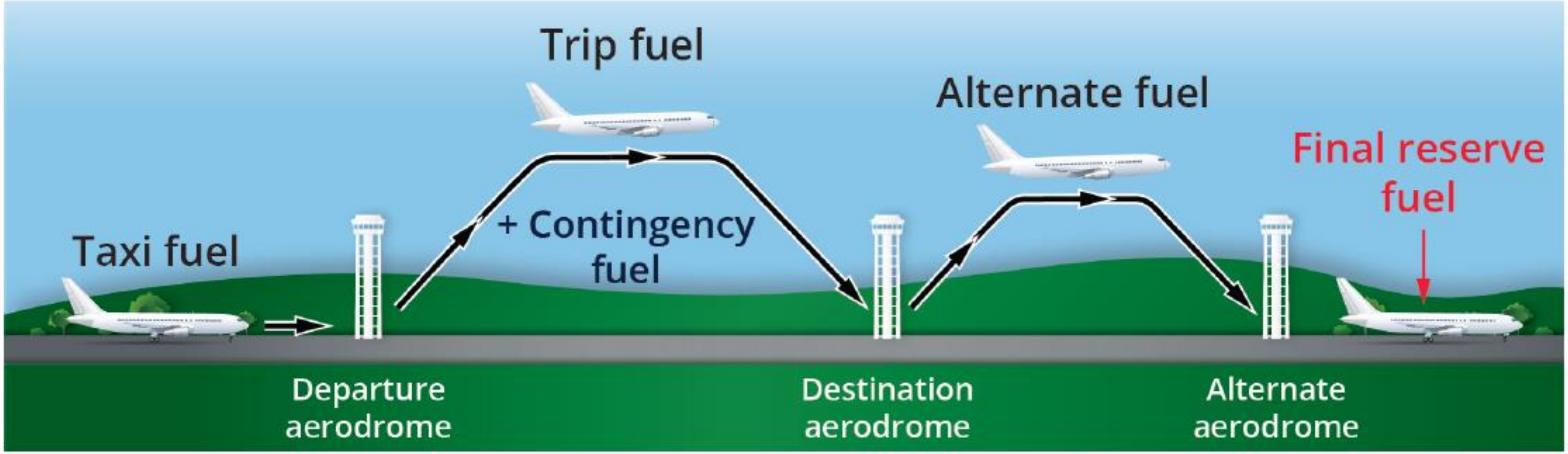
Dry operating mass 34,200 kg + traffic load 12,560 kg = Zero fuel mass 46,760 kg

Traffic load 11,920 lb+ useable fuel 15,300 lb = Useful load 27,220 lb

Basic empty mass 33,190 kg + variable load 3,740 kg = Dry operating mass 36,930 kg

Fuel Conversion

It is the responsibility of the pilot in command to ensure that there is sufficient fuel onboard the aeroplane to safely complete the intended flight and to not land with less fuel in the tanks than legally required, irrespective of delays or diversions.



Having determined the mass of the required fuel for a sector, the pilot in command may need to convert this mass value into a quantity value for the benefit of the refuel operator. Fuel is sometimes dispensed in gallons or litres. In order to convert quantity (gallons or litres) into mass (pounds or kilograms) and vice versa, the density or the specific gravity (SG) of the fuel must be known. The refuel operator provides the SG of the fuel uplifted. However, if the actual fuel density is not known, conversion of fuel volume to mass may be done by using standard fuel density values as specified in the Operations Manual.

Density is defined as mass per unit volume and relative density or specific gravity (SG), is simply a comparison between the mass of a certain volume of a substance and the mass of an equal volume of pure water.

When moving in the direction of the arrows multiply by the numbers above the line. When moving against the direction of the arrows divide by the numbers above the line.

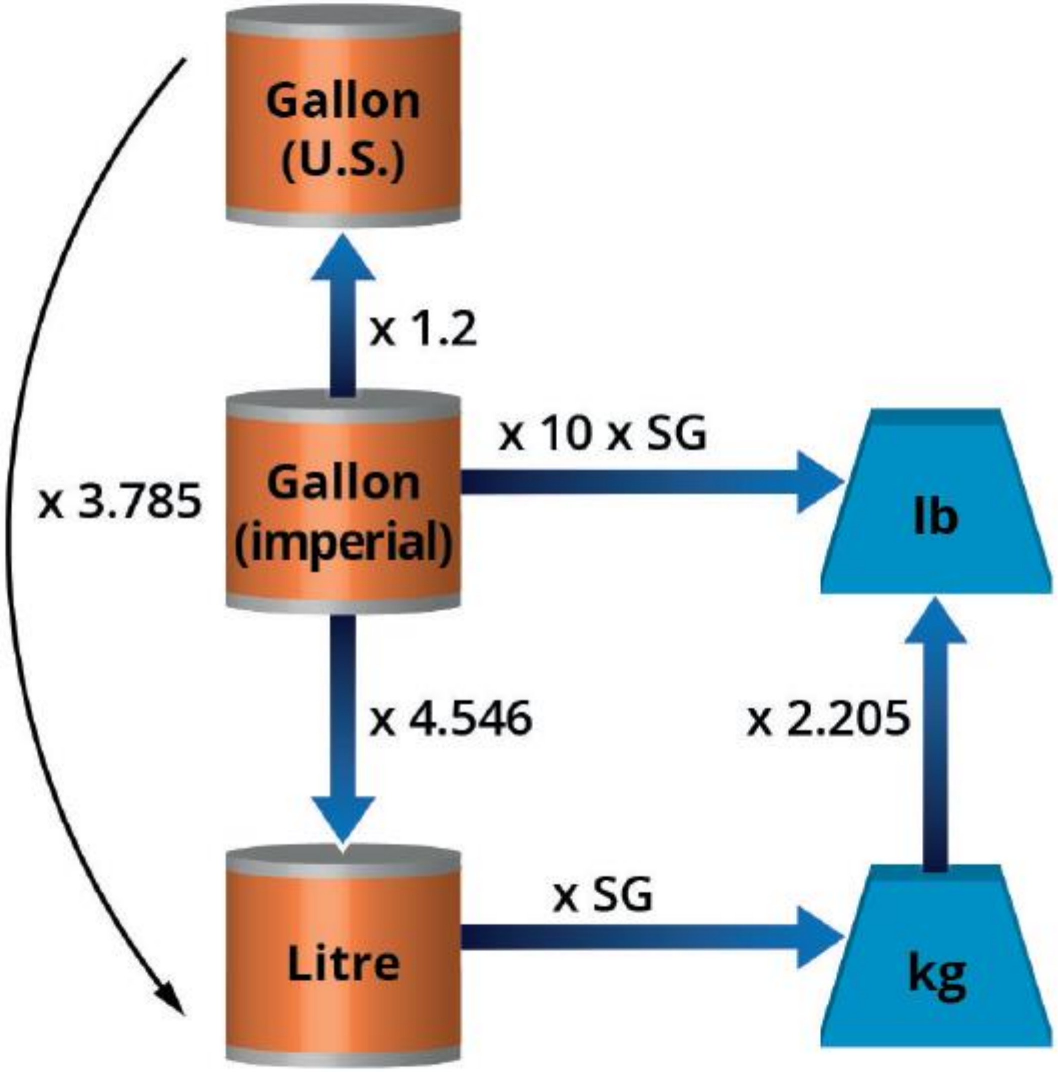


Figure 2.4 Fuel conversion chart

Example 1

a) Find the mass of 50 imperial gallons of AVGAS with a specific gravity of 0.72.

Mass = 50 × 10 × 0.72 = 360 lb

b) For 50 US gallons this would be:

Mass = 50 × 3.785 × 0.72 = 136.26 kg

Example 2

Find the mass of 2,250 litres of fuel with a density of 0.82.

Mass = 2,250 × 0.82 = 1,845 kg.

Mass Limits

Introduction

There are two types of mass limitations, structural and performance. There are four structural limitations which are set figures for each particular aircraft given the most favourable conditions anywhere in the world.

- Maximum zero fuel mass
- Maximum ramp/taxi mass
- Maximum structural takeoff mass
- Maximum structural landing mass

There are two performance limitations which must also never be exceeded. These are not set figures and will change with many factors. Some examples are density, air temperature, airfield elevation, runway length or the topography of the area.

- Performance limited takeoff mass
- Performance limited landing mass

Note that there are two limits for takeoff mass and two limits for landing mass. Both limitations must be analysed and the most restrictive must be selected. The lower of the structural and performance limitations is called the regulated mass.

Structural Limitations

Maximum Zero Fuel Mass

The maximum zero fuel mass (MZFM) is the maximum permissible mass of an aeroplane with no usable fuel. The maximum stress in the wing roots occurs when the wing fuel tanks are empty. To ensure the aircraft does not suffer any structural damage as the fuel is consumed, a maximum zero fuel mass is imposed by the manufacturer.

Maximum Ramp/Taxi Mass

The maximum ramp mass / taxi mass is the maximum permissible mass of an aeroplane at the ramp. There is an allowance of fuel permitted for engine starting and ground taxiing purposes. This fuel, which is limited to a maximum value, is allowed to take the weight of the aircraft above the maximum structural takeoff mass (MSTOM) during ground operations only. The fuel for engine starts and taxiing should be consumed by the time the aircraft is ready to commence the takeoff run.

Maximum Structural Takeoff Mass

The maximum structural takeoff mass (MSTOM) is the maximum permissible total aeroplane mass at the start of the takeoff run given the most favourable conditions anywhere in the world. It is a set structural limitation and does not change for a particular aircraft. If the MSTOM is exceeded structural damage can occur to the aircraft.

Maximum Structural Landing Mass

The maximum structural landing mass (MSLM) is the maximum permissible total aeroplane mass on landing in normal circumstances and given the most favourable conditions anywhere in the world. It is a set structural limitation and does not change for a particular aircraft. If the MSLM is exceeded structural damage can occur to the aircraft.

Performance and Regulated Limitations

Performance Limited Takeoff Mass

The performance limited takeoff mass (PLTOM) is the maximum permissible total aeroplane takeoff mass subject to departure aerodrome limitations also taking the current metrological conditions into account. This limit is not a set figure and needs to be calculated for each sector. If the PLTOM is exceeded the aircraft may not have enough takeoff distance available or stopping distance in case of a rejected takeoff, climb requirements may not be met and there is a risk of structural fatigue.

Performance Limited Landing Mass

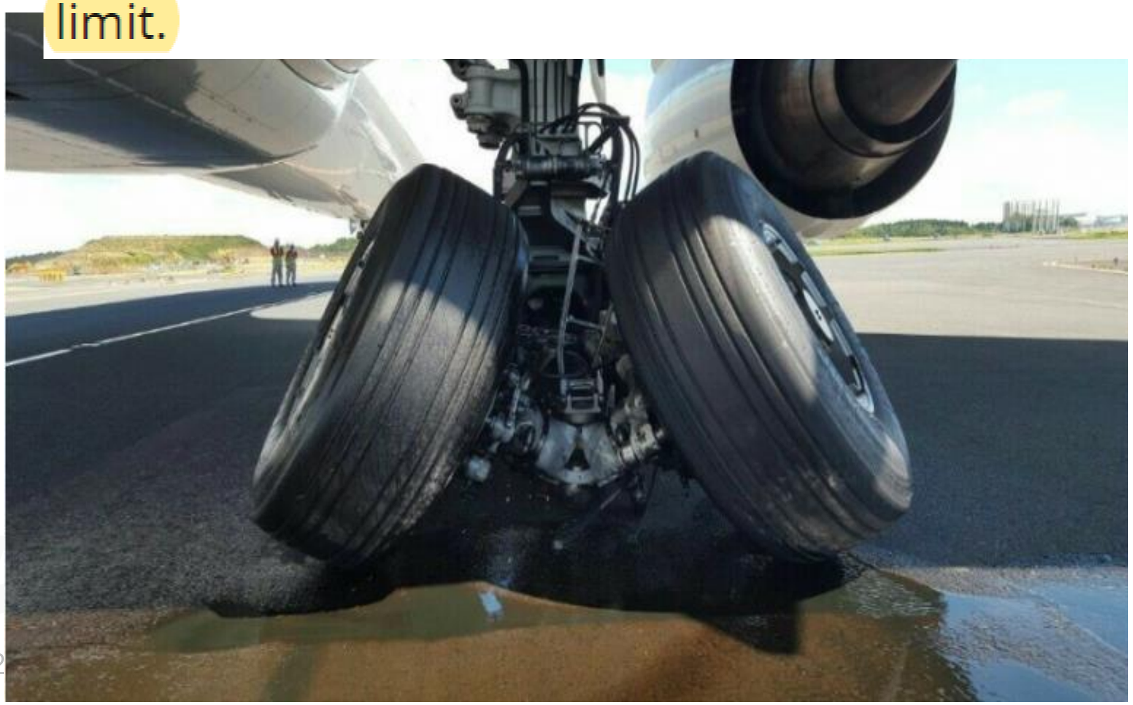
The performance limited landing mass (PLLM) is the maximum permissible total aeroplane mass subject to the landing aerodrome limitations also taking the current metrological conditions into account. This limit is not a set figure and needs to be calculated for each sector. If the PLLM is exceeded the aircraft may overrun the landing distance available, tyre temperature limits could be exceeded, a go-around might not be achievable and there is a risk of structural fatigue.

Regulated Takeoff Mass

The regulated takeoff mass (RTOM) is the lowest of the performance limited takeoff mass and maximum structural limited takeoff mass. The actual takeoff mass must not exceed this limit.

Regulated Landing Mass

The regulated landing mass (RLM) is the is the lowest of the performance limited landing mass and maximum structural limited landing mass. The actual landing mass must not exceed this limit.



Mass Calculations

None of the structural or performance limitations are permitted to be exceeded. In order to ensure the aircraft remains within all of the limitations, a calculation is required to check which is the most restrictive on that particular flight. The single most restrictive limitation is called the **allowed takeoff mass (ATOM).**

The limitations we need to consider are:

- Maximum zero fuel mass
- Maximum ramp/taxi mass
- Regulated takeoff mass (lower of MSTOM and PLTOM)
- Regulated landing mass (lower of MSLM and PLLM)

As these limitations are at different stages of the flight it would be difficult to compare them in their current format. Therefore, we use the takeoff position as a reference point and convert MZFM, MRM and RLM limitations. The difference between these positions is the amount of fuel.

- To convert MZFM limit to the takeoff reference, takeoff fuel is required to be added.
- To convert MRM limit to the takeoff reference, taxi fuel is required to be subtracted.
- To convert RLM limit to the takeoff reference, trip fuel is required to be added.

ATOM Example

Maximum ramp mass: 73,000 kg

Maximum zero fuel mass: 59,750 kg

Maximum structural takeoff mass: 72,700 kg

Maximum structural landing mass: 63,300 kg

Performance limited takeoff mass: 72,950 kg

Performance limited landing mass: 62,100 kg

Block fuel: 16,200 kg. Taxi fuel: 260 kg

Trip fuel: 10,400 kg

	MRM	MZFM	RTOM	RLM
Limit	73,000 kg	59,750 kg	72,700 kg	62,100 kg
Fuel	Subtract taxi fuel - 260 kg	Add takeoff fuel + 15,940 kg		Add trip fuel + 10,400 kg
ATOM	72,740 kg	75,690 kg	72,700 kg	**72,500 kg**

Solution: Choose the RTOM and RLM.

The lowest (and most restrictive) is the allowed takeoff mass.

In the above ATOM mass calculation, the aircraft is landing mass limited and this will determine all other masses, for example: If the stated fuel values remain the same, the zero fuel mass could not exceed 56,560 kg (ATOM 72,500 kg – takeoff fuel 15,940 kg).

Many aircraft cannot carry both its maximum allowed traffic load and maximum allowed fuel load at the same time. Therefore, due to the structural and performance limitations we may need to reduce payload in order to carry the fuel required for flight. If fuel carried is reduced to accommodate payload EU-OPS fuel regulations must still be met.

Maximum Allowed Traffic Load

To calculate the maximum allowed traffic load the aircraft can carry, subtract the dry operating mass (DOM) and actual takeoff fuel (TOF) from the allowed takeoff mass (ATOM).

ATOM – DOM – TOF = Maximum traffic load

This can also be expressed as, ATOM – OM = Maximum traffic load (as OM = DOM + TOF)

Example

Maximum zero fuel mass: 109,500 kg

Regulated takeoff mass: 145,000 kg

Regulated landing mass: 124,000 kg

Dry operating mass: 82,000 kg

Scheduled trip fuel: 17,000 kg

Reserve fuel: 6,000 kg

No MRM is given in this example calculation. When any of the limitations are excluded, assume that it is not limiting and does not need to be included in the calculations.

Solution:

	MZFM	RTOM	RLM
Limit	109,500 kg	145,000 kg	124,000 kg
Fuel	Add takeoff fuel + 23,000 kg		Add trip fuel + 17,000 kg
ATOM	**132,500 kg**	145,000 kg	141,000 kg
Substract OM (DOM +TOF)	-105,000 kg		
Max Allowed Traffic Load	**27,500 kg**		

Figure 2.6 Maximum allowed traffic load table

In the above calculation, the aircraft is maximum zero mass limited, and the maximum allowed traffic load which can be carried is 27,500 kg.

Maximum Allowed Fuel Load

To calculate the maximum allowed fuel load the aircraft can carry, subtract the dry operating mass (DOM) and actual traffic load (TL) from the allowed takeoff mass (ATOM).

$$ATOM - DOM - TL = Maximum\ allowed\ fuel\ load$$

When asked to calculate the maximum allowed fuel load, maximum zero fuel mass should not be included as a limitation in the calculations.

MZFM is the DOM plus traffic load (TL). It does not include any useable fuel, and therefore will not limit the maximum allowed fuel load the aircraft can carry.

Example

Maximum zero fuel mass: 65,000 kg

Maximum structural takeoff mass: 80,000 kg

Maximum structural landing mass: 73,500 kg

Dry operating mass: 37,600 kg

Traffic load: 17,500 kg

Trip fuel: 7,200 kg

Performance limitations are not restricting.

Again, if any of the limitations are excluded, assume that it is not limiting and does not need to be included in the calculations.

Remember not to use MZFM limitation when calculating maximum allowed fuel load.

Solution

	RTOM	RLM
Limit	80,000 kg	73,500 kg
Fuel		Add trip fuel + 7,200 kg
ATOM	**80,000 kg**	80,700 kg
Substract DOM	-37,600 kg	
Substract Traffic Load	-17,500 kg	
Max Allowed Takeoff Fuel	24,900 kg	

In the above calculation, the aircraft is takeoff mass limited, and the maximum allowed fuel load which can be carried at the takeoff position is 24,900 kg. However, aircraft are refuelled at the ramp and not at takeoff position. To find the maximum allowed ramp fuel taxi fuel should be added.

It is important to check whether the maximum allowed fuel at takeoff position or at the ramp has been asked to calculate.

Example

Maximum ramp mass: 63,060 kg

Maximum zero fuel mass: 51,300 kg

Regulated takeoff mass: 62,500 kg

Regulated landing mass: 54,900 kg

Dry operating mass: 34,200 kg

Scheduled trip fuel: 9,100 kg

Reserve fuel: 5,700 kg

Taxi fuel: 300 kg

Passengers: 6,398 kg

Baggage: 940 kg

Cargo: 2,800 kg

Calculate the actual traffic load from the above details:

Passengers: 6,398 kg + Baggage: 940 kg + Cargo: 2,800 kg = Traffic Load: 10,138 kg.

Solution:

Example

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Passengers: 6,398 kg + Baggage: 940 kg + Cargo: 2,800 kg = Traffic Load: 10,138 kg.

Solution:

	MRM	MZFM	RTOM	RLM
Limit	63,060 kg	51,300 kg	62,500 kg	54,900 kg
Fuel	Subtract taxi fuel - 300 kg	Add takeoff fuel + 14,800 kg		Add trip fuel + 9,100 kg
ATOM	62,720 kg	66,100 kg	**62,500 kg**	64,000 kg
Substract OM (DOM +TOF)			-49,000 kg	
Allowed Traffic Load			13,500 kg	
Substract Actual Traffic Load			-10,138 kg	
Underload / Overload			3,362 kg	

In the above calculation, the aircraft is takeoff limited. The maximum allowed traffic load is 13,500 kg. An actual traffic load of 10,138 kg is planned, meaning there is an underload of 3,362 kg.

Standard masses are permitted to be used instead of actual masses. The regulations for use are outlined in EU-OPS.

Aviation authorities may give permission for different standard masses if required. The operator must advise the reasons required with detailed weighing survey plan and statistical analysis.

Standard Masses for Passengers

For use of the standard mass tables for passengers, an adult is defined as a person aged 12 and above. Children are defined as being 2 years and above but less than 12 years of age. Infants are defined as less than 2 years of age. Infants occupying a seat are considered the same mass as children (35 kg).

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