a) **BOLT SHEAR STRESS:**

This is the failure mode that occurs when the bolts used to hold the closure into the casing break due to the force applied perpendicular to the axis of the fastener. It is most likely to occur in designs with few fasteners of relatively small diameter, and is the only failure mode not affected by casing wall thickness.

Number of Bolts Calculation

Given Data:

- Maximum yield stress of mild steel: $250MPa$
- Safety factor: 1.67
- Shear stress according to von Mises criterion is $60\%\ of\ yield\ stress\ =\ 150MPa$
- Diameter of M6 bolt: 6mm
- Chamber pressure (Pmax): $4.26MPa$
- Cross-sectional area of casing calculated based on inner diameter $94mm$
- Airframe weight: $15.2kg$

Calculations:

Maximum Allowable Shear Stress:

$$\tau max\ =\ \frac{150MPa}{1.67} \approx 90MPa$$

Shear Stress on One Bolt:

$Area\ of\ M6\ bolt\ = \frac{\pi}{4} * 6^2\ =\ 28.274mm^2$ 28.274mm2

$$Force\ per\ bolt\ =\ \tau max \times Area \times 2\ =\ 90MPa \times 28.274mm^2 \times 2\ =\ 5089.32N$$

Total Force Calculation:

- **Force due to Chamber Pressure:**
  $Fchamber\ =\ Pmax \times Cross\ -\ sectional\ Area\ =\ 4.26MPa \times \frac{\pi}{4} \times 94^2\ =\ 29563.46N$
- **Force due to Airframe Resistance:**

  $Fairframe\ =\ Weight\ of\ Airframe \times g\ =\ 15.2kg \times 9.81m/s^2\ =\ 149.112N$

- **Total Force:**

$$Ftotal = Fchamber + Fairframe = 29563.46N + 149.112N = 29712.572N$$

Number of Bolts Required:

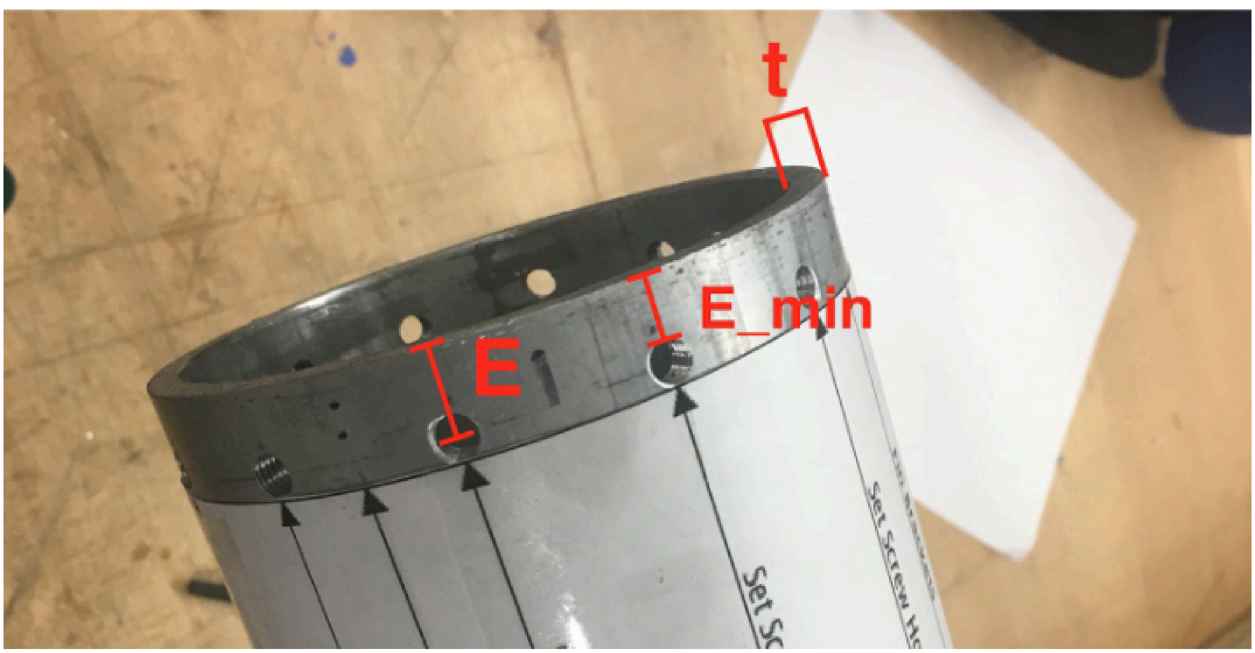
$$Number\ of\ bolts = \frac{Ftotal}{Force\ per\ bolt} = \frac{29712.572N}{5089.32N} \approx 5.84$$

Since the number of bolts must be an integer, we round up to ensure sufficient capacity:

Number of bolts=**6**

b) BOLT TEAR-OUT STRESS:

Bolt tear-out is the failure in which the bolts tear through the aluminum motor casing. It is most likely to occur in designs in which the fastener holes are very close to the edge of the casing, or the casing wall is relatively thin. This type of failure is the result of shear stresses in the aluminum casing wall.



Note that $E \geq 2d\ (bolt\ major\ diameter)$ is highly recommended

And so $E\ >=\ 2 * 6mm\ >=\ 12mm$

$$E(min) = E - \frac{d(bolt,major)}{2} = 12 - \frac{6}{2} = 9mm$$

$$\sigma tearout \; = \; \frac{Fbolt}{E\,min * 2t} \; = \; \frac{5089.32}{9 * 2 * 3} \; = \; 94.25 MPa$$

Shear strength is given as $152\ MPa$ for Aluminium 6063-T6.

c) BEARING STRESS

Bearing failure occurs when the force of the bolts pushing against the edges of their holes causes the casing material to fail in compression.

Bearing yield strength is given as $276MPa$ for Aluminium 6063-T6.

$$\sigma(bearing) \; = \; \frac{F(bolt)}{d(bolt\ major) * t} \; = \; \frac{5089.32}{6 * 3} \; = \; 282.74MPa$$

Using a safety factor of 1.5, maximum allowable bearing pressure = $184MPa$

$$\sigma(bearing) \; = \; \frac{F(bolt)}{d(bolt\ major) * t} \; => Fbolt \; = \; 184 \; * \; 6 \; * \; 3 \; = \; 3312N$$

$$Number\ of\ bolts = \frac{Ftotal}{Force\ per\ bolt} \; = \; \frac{29712.572N}{3312N} \; = \; 8.9 \approx 10\ bolts$$

d) CASING TENSILE STRESS

Casing tensile failure occurs when the portion of the aluminum casing between the fastener holes is stretched beyond its breaking point.

$$\sigma tensile \; = \; \frac{F(due\ to\ chamber\ pressure)}{[(D\ outer\ diameter\ of\ casing - t)\pi - N * d(bolt\ major)] * t} \; = \frac{29563.46}{[(100-3)\pi - 10 * 6] * 3} \; = \; 40.26MPa$$

Aluminum 6063-T6 has a yield strength of at least **160 MPa**