LAB #2  YIELD CRITERIA / FAILURE THEORIES

FBD OF TIRE & WHEEL (FIND HUB REACTIONS)

Braking Force
(0.3) 3001N = 900N

Cornering Load
(0.4) 3001N = 1201N

Weight of Truck on Tire
1225kg(9.8 m/s²) = 3001N

R = (17in)² / 2 + 0.4(235mm) = 310mm = 0.31m

M₂ = 279 Nm
Rₓ = 1201N
Rᵧ = 3001N
Rₗᵧ = 372 Nm

FBD OF HUB: (ENLARGED TO SHOW DETAIL; FIND BEARING REACTIONS)

Braking Torque from Wheel
279 Nm

Torque from Brake Rotor
279 Nm (NOT FELT IN SPINDLE)

Rₓ = 1201N
Rᵧ = 3001N
Rᵧ = 5221N
Rₒ = 450N

Fᵧ = 0; Rᵧ = 3001N
Fₓ = 0; Rₓ + Rₒ = 900N
Mᵧ = 0; 900N(0.05m) = Rₒ(0.10m) → Rₒ = 450N & Rₒ = 450N
Mₓ = 0; -Rᵧ(0.10m) + 372 Nm + 3001N(0.05m) = 0
Rᵧ = 5221N & Rᵧ = 2220N
Finally, the FBD of the spindle: (Find steering knuckle reactions)

\[ F_x = 0; \quad R_{Fx} = 1,201 \text{ N} \]
\[ F_y = 0; \quad R_{Ky} = 2,220 - 522 = 1,701 \text{ N} \]
\[ F_z = 0; \quad R_{Kz} = 450 + 450 = 900 \text{ N} \]
\[ M_{Fx} = 0; \quad 0 = 0 \]
\[ M_{Fy} = 0; \quad M_{Ky} = 450 \text{ Nm} (0.10 \text{ m}) = 45 \text{ Nm} \]
\[ M_{Fz} = 0; \quad M_{Kz} = 5,221 \text{ Nm} (0.10 \text{ m}) = 522 \text{ Nm} \]

Shear and Bending Moment Diagrams:

**Horizontal (x-z Plane):**

- \( V \) \[ 450 \text{ N} \]
- \( M \) \[ 45 \text{ Nm} \]

**Vertical (y-x Plane):**

- \( V \) \[ 522 \text{ N} \]
- \( M \) \[ 522 \text{ Nm} \]
LAB #2 (CONT'D)

MAXIMUM BENDING MOMENT = \( M_{\text{max}} = \sqrt{45^2 + 522^2} = 524 \text{ Nm} \)

MAXIMUM SHEAR = \( V_{\text{max}} = \sqrt{450^2 + 5221^2} = 5240 \text{ N} \)

\[ \sigma_b = \frac{M_c}{I} = \frac{32M}{\pi D^3} = \frac{32(524 \text{ Nm})}{\pi (0.03 \text{ m})^3} = 198 \text{ MPa (MAX BENDING STRESS)} \]

\[ \tau_b = \frac{4V}{3A} = \frac{4(5240 \text{ N})}{3 \pi (0.03 \text{ m})^2} = 9.98 \text{ MPa (MAX TRANSVERSE SHEAR STRESS)} \]

\[ \sigma_a = \frac{P}{A} = \frac{1201 \text{ N}}{\pi (0.03 \text{ m})^2} = 1.70 \text{ MPa (MAX AXIAL STRESS)} \]

The critical point is the point of maximum stress; i.e. the point where the fracture would start if the part actually broke. Above, the maximum stresses have been calculated but these exist at different places in the spindle!

The bending stress above will obviously dominate, so we look at that point. This max bending stress exists where the spindle meets the steering knuckle, but only on the "top & bottom" of the shaft.

END VIEW OF SHAFT:

Max bending from 522 Nm moment

45 Nm bending

Max bending from 45 Nm moment

Max bending from 522 Nm moment

OR

Approx. location of max bending stress due to 524 Nm moment

This is the crit. point.

Exact location need not be calculated.
AT THE CRITICAL POINT JUST DESCRIBED, BOTH THE Axial stress & Bending Stress are present, the transverse shear stress is zero here. Thus we must use von Mises to find the equivalent stress at this point.

\[
\text{von Mises} = \sqrt{\sigma_x^2 + \sigma_y^2 - 2\sigma_x\sigma_y + 3\tau_{xy}^2}
\]

\[
= \sqrt{(198 + 1.70)^2 + 0 - 0 + 0}
\]

\[
= 200 \text{ MPa} = \sigma' \text{ or } \sigma_{eq}
\]

Factor of safety in yield = \[
\frac{S_y}{\sigma'} = \frac{1462 \text{ MPa}}{200 \text{ MPa}}
\]

\[
= 7.3
\]