MECH 202 Mini Project
Real-Life Structure Analysis

Front Suspension Fork of VIVI F26FUL E-Bike

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1 Object and Observed Failure

The object I chose is the **front suspension fork** from my VIVI F26FUL fat-tire electric bicycle. The bike has 26" $\times$ 4.0" tires, an aluminum frame, and a front suspension fork made from high-strength steel.

The fork consists of:

- a steerer tube that fits into the frame and handlebars,
- a crown that ties the two sides together,
- two upper tubes (stanchions),
- two lower legs which slide on the stanchions and hold the front wheel axle, connected by an arch above the tire.

I was involved in a crash where I hit the front of the side of a car. Afterwards, one **upper tube (stanchion)** was **permanently bent near the top**, right where it is fixed into the crown, while the other side stayed almost straight. The wheel and tire were not damaged. This suggests that the top of the upper tube at the crown joint is the weakest section in bending and will be the focus of the analysis.

Figure 1: Front suspension fork mounted on the bike before the accident, showing both upper tubes and lower legs straight and aligned.

Figure 2: Same front suspension fork after the accident, removed from the bike, with one upper tube clearly bent near the crown while the other side remains straight."

2 Loading Scenario and Free-Body Diagram

The fork mainly sees front–back bending loads when braking or when the front wheel hits something. I consider two loading cases:

1. **Hard braking (normal use).**
2. **Crash into the car (severe impact).**

To keep numbers reasonable, I use:

- Rider mass $m_r = 63$ kg,
- Bike mass $m_b = 34$ kg,
- Total mass $m = m_r + m_b = 97$ kg,
- Distance from axle to the top of the upper tube (stanchion) where it is fixed in the crown (critical section) $L \approx 0.35$ m,
- The two fork legs share the load equally.

Case 1: Hard Braking

Assume a strong deceleration of about $0.8g$:

$$a = 0.8 \times 9.81 \approx 7.85 \text{ m/s}^2.$$

Horizontal force at the tire–ground contact:

$$F = ma = 97 \times 7.85 \approx 761 \text{ N} \approx 760 \text{ N}.$$

Each fork leg carries half:

$$F_{\text{leg}} = \frac{F}{2} \approx \frac{760}{2} = 380 \text{ N}.$$

Case 2: Crash into the Car

In the crash the front wheel stopped almost instantly, so the force is much higher than in braking. I model it as

$$F_{\text{crash}} \approx 3000 \text{ N}, \qquad F_{\text{leg,crash}} = \frac{F_{\text{crash}}}{2} = 1500 \text{ N}.$$

Free-Body Diagram

In side view, the combined fork + wheel has:

- a backward horizontal force F at the tire–ground contact,
- an equal forward reaction at the headset,
- internal forces and moments in the fork legs.

Each side (upper tube plus lower leg assembly) can be modeled as a **cantilever beam**: fixed at the top of the upper tube in the crown, with a horizontal load applied at the bottom (the axle). The bending moment at the top of one upper tube is

$$M = F_{\text{leg}}\, L$$

and the shear force there is

$$V = F_{\text{leg}}.$$

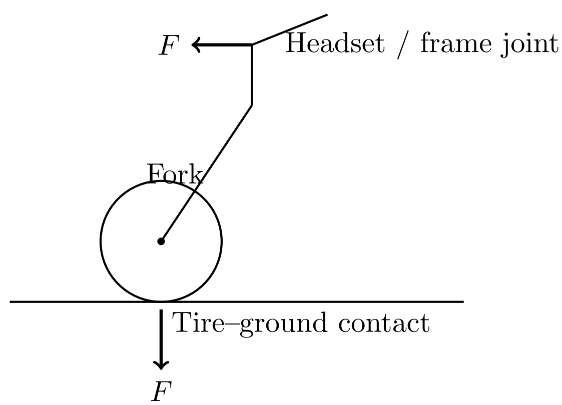

Figure 3: Free-body diagram of fork and wheel in side view, showing horizontal forces during braking / impact.

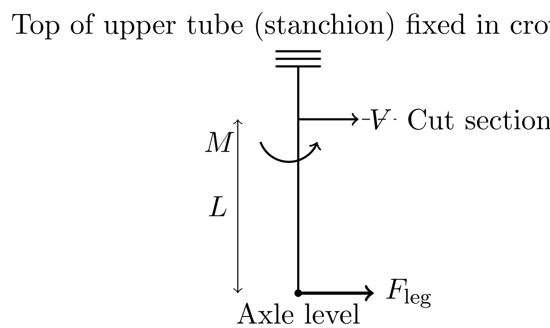

Figure 4: One side of the fork idealized as a cantilever with the upper tube fixed in the crown and a horizontal load at the axle.

Numerically,

$$M_1 = 380 \times 0.35 \approx 133 \text{ N} \cdot \text{m}, \qquad M_2 = 1500 \times 0.35 = 525 \text{ N} \cdot \text{m},$$

for the braking and crash cases, respectively.

3 Geometry, Material, and Stress Calculations

Near the top, the upper tube (stanchion) is approximately a hollow circular tube. I use:

$$D_o = 32 \text{ mm} = 0.032 \text{ m}, \qquad D_i = 26 \text{ mm} = 0.026 \text{ m}.$$

Cross-sectional area:

$$A = \frac{\pi}{4}\left(D_o^2 - D_i^2\right) = \frac{\pi}{4}\left(0.032^2 - 0.026^2\right) \approx 2.73 \times 10^{-4} \text{ m}^2.$$

Second moment of area:

$$I = \frac{\pi}{64}\left(D_o^4 - D_i^4\right) = \frac{\pi}{64}\left(0.032^4 - 0.026^4\right) \approx 2.90 \times 10^{-8} \text{ m}^4.$$

Distance from neutral axis to the outer surface:

$$c = \frac{D_o}{2} = 0.016 \text{ m}.$$

The fork is advertised as high-strength steel. I use a typical yield strength for a medium-carbon steel,

$$\sigma_y \approx 250 \text{ MPa}.$$

Bending Stress

For a beam in bending,

$$\sigma_\mathrm{b} = \frac{Mc}{I}.$$

Case 1: Hard braking.

$$\sigma_{b1} = \frac{M_1 c}{I} = \frac{133 \times 0.016}{2.90 \times 10^{-8}} \approx 7.3 \times 10^7 \text{ Pa} \approx 73 \text{ MPa}.$$

Case 2: Crash.

$$\sigma_{b2} = \frac{M_2 c}{I} = \frac{525 \times 0.016}{2.90 \times 10^{-8}} \approx 2.89 \times 10^8 \text{ Pa} \approx 289 \text{ MPa}.$$

So the bending stress at the outer surface of the top of the upper tube is about 73 MPa during hard braking and about 289 MPa in the crash case.

Shear Stress

A rough average shear stress is

$$\tau \approx \frac{V}{A}.$$

For hard braking,

$$\tau_1 = \frac{380}{2.73 \times 10^{-4}} \approx 1.4 \times 10^6 \text{ Pa} \approx 1.4 \text{ MPa},$$

and for the crash,

$$\tau_2 = \frac{1500}{2.73 \times 10^{-4}} \approx 5.5 \times 10^6 \text{ Pa} \approx 5.5 \text{ MPa}.$$

These are much smaller than the bending stresses, so the failure is bending-dominated, which matches the visible bent shape of the upper tube.

4 Factor of Safety and Discussion

With yield strength $\sigma_y = 250$ MPa:

Normal Hard Braking

$$\text{FoS}_1 = \frac{\sigma_y}{\sigma_{b1}} = \frac{250}{73} \approx 3.4.$$

A factor of safety a bit above 3 suggests the fork is safe for normal hard braking and rough riding, which agrees with everyday experience.

Crash into the Car

$$\text{FoS}_2 = \frac{\sigma_y}{\sigma_{b2}} = \frac{250}{289} \approx 0.87 < 1.$$

Here the factor of safety is below 1, so the steel at the top of the upper tube yields and does not return to its original shape. This explains why one stanchion stayed bent after the crash.

Because of small geometric differences and the disc brake mount, the two sides probably did not share the load perfectly. The damaged side may have carried more than half the load, pushing its stress even higher and making yielding more likely.

5 Design Evaluation and Improvements

Why the Bend Happens at the Top

- The top of the upper tube (stanchion), where it is fixed into the crown, is the "fixed" end of the cantilever, where the bending moment is largest, so it is the natural location for maximum bending stress.
- At this spot the round tube shape blends into the crown / steerer assembly. Changes in geometry and any sharp corners act as stress concentrators, increasing the local peak stress.
- Slight asymmetry and the front disc brake mean one side can see more load than the other, so that stanchion may yield first, which is what happened in my crash.

Under normal riding the design seems adequate (FoS ≈ 3.4), but under a strong frontal impact the top of the upper tube at the crown joint is clearly the weak link.

Possible Improvements

1. **Increase stiffness at the critical zone:** slightly increase the outer diameter or wall thickness in just the top 50–70 mm of the upper tube to increase I and reduce $\sigma = Mc/I$.

2. **Reduce stress concentrations:** use larger fillet radii and smoother transitions where the upper tube meets the crown and internal features; avoid sudden thickness changes and sharp internal corners.

3. **Improve load sharing:** make the arch and crown stiffer so the two sides share impact loads more evenly.

Conclusion

By modeling one side of the VIVI F26FUL e-bike fork as a hollow steel cantilever with the upper tube fixed in the crown, I found a bending stress of about 73 MPa during hard braking (factor of safety ≈ 3.4) and about 289 MPa during the crash into the car (factor of safety ≈ 0.87). The calculations match the real damage: the top of one upper tube (stanchion) yielded and stayed bent. The analysis shows that the fork is safe in normal use but not very strong against large frontal impacts. Geometric changes at the top of the upper tube where it is fixed into the crown could improve the design without changing how the fork works.