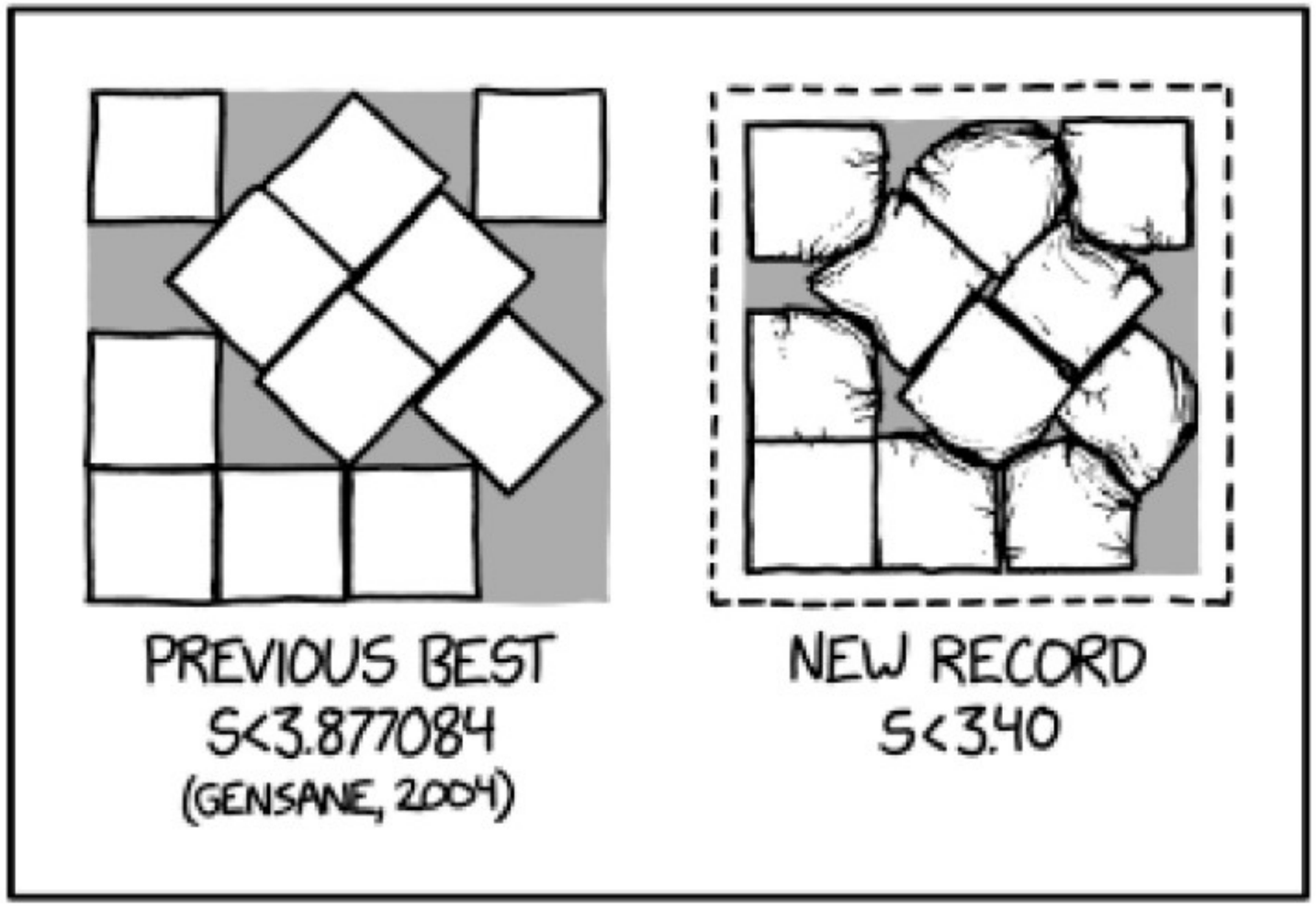
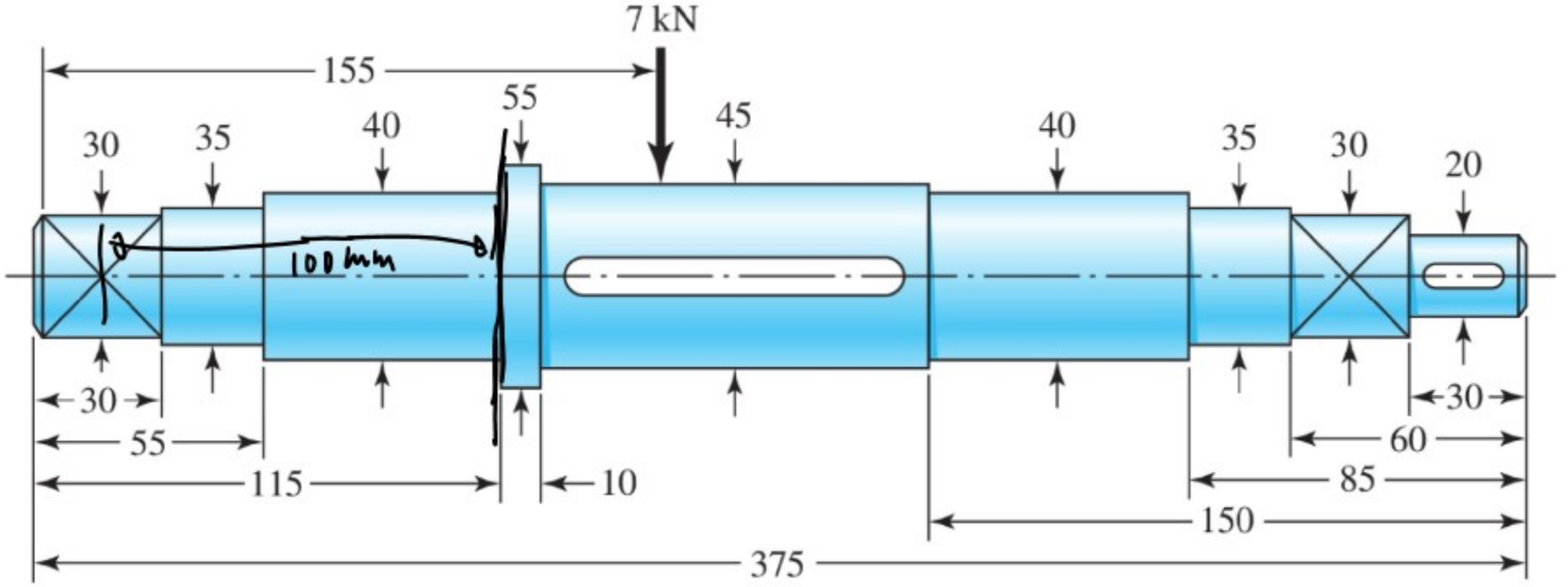


I'VE SIGNIFICANTLY IMPROVED ON THE SOLUTION TO THE N=11 SQUARE PACKING PROBLEM BY USING A HYDRAULIC PRESS.

An AISI 1020 cold-drawn steel shaft with the geometry shown in the figure carries a transverse load of 7 kN and a torque of 107 N · m. Examine the shaft for strength and deflection. If the largest allowable slope at the bearings is 0.001 rad and at the gear mesh is 0.0005 rad, what is the factor of safety guarding against damaging distortion? Using the DE-Goodman criterion, what is the factor of safety guarding against a fatigue failure? If the shaft turns out to be unsatisfactory, what would you recommend to correct the problem?



All fillets 2 mm

$$y'(0) = \frac{-1.40 \times 10^9}{E} = \frac{-1.4 \times 10^9}{207 \times 10^9} = -0.0068$$

$$y'(0.14) = \frac{-1.31 \times 10^9}{E} = \frac{-1.31 \times 10^9}{207 \times 10^9} = -0.0063$$

$$y'(0.315) = \frac{-330 \times 10^6}{E} = \frac{-330 \times 10^6}{207 \times 10^9} = -0.004$$

$n_d = 2$

$$d_{new} = d_{old} \left| \frac{n_d \left(\frac{dy}{dx}\right)_{old}}{slope_{all}} \right|^{1/4} = d_{old} \left| \frac{2(-0.0063)}{0.001} \right|^{1/4}$$

$$= d_{old}\ 1.92$$

$$d_{new} = d_{old} \left| \frac{2(-0.0063)}{0.0005} \right|^{1/4} = d_{old}\ 2.24$$

$$d_{new} = d_{old} \left| \frac{2(-0.004)}{0.001} \right|^{1/4} = d_{old}\ 1.68$$

$$n = \frac{\pi d^3}{16}\left(\frac{A}{S_e} + \frac{B}{S_{ut}}\right)^{-1} = \frac{\pi (0.09)^3}{16}\left(\frac{1556}{157\times10^6} + \frac{329}{970\times10^6}\right)^{-1} = 1.19$$

$$A = \sqrt{4(K_f M_a)^2 + 3(K_{fs} T_a)^2} = 2K_f M_a = 2(2)(388.9) = 1556$$

$$B = \sqrt{4(K_f M_m)^2 + 3(K_{fs} T_m)^2} = \sqrt{3}\, K_{fs} T_m = \sqrt{3}\,1.75(107) = 329$$

$$M_a = 3889x = 3889(0.1) = 388.9$$

$$D/d = 55/40 = 1.375 \qquad K_{fs} = 1.75$$

$$r/d = 2/40 = 0.05 \qquad K_f = 2$$

$$S_{ut} = 470\ MPa \qquad S_e' = 0.5\, S_{ut} = 235\ MPa$$

$$S_e = S_e' K_a K_b K_c K_d K_e = 235(0.8)1.24(40)^{-0.107}1 = 157\ MPa$$

The shaft shown in the figure is driven by a gear at the right keyway, drives a fan at the left keyway, and is supported by two deep-groove ball bearings. The shaft is made from AISI 1020 cold-drawn steel. At steady-state speed, the gear transmits a radial load of 230 lbf and a tangential load of 633 lbf at a pitch diameter of 8 in.

(*a*) Determine fatigue factors of safety at any potentially critical locations using the DE-Gerber failure criterion.

(*b*) Check that deflections satisfy the suggested minimums for bearings and gears.