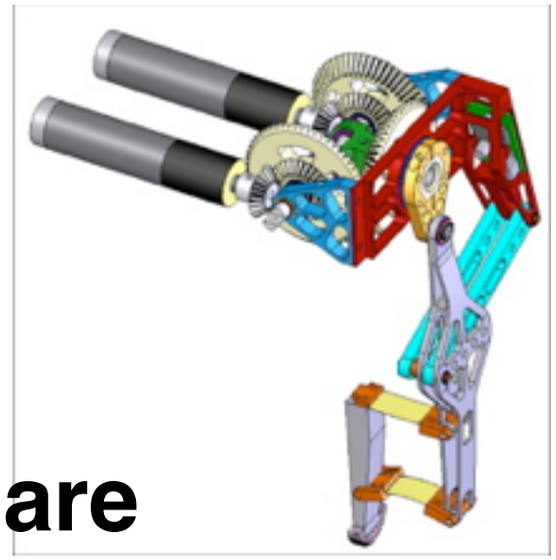
ME112: Mechanical Systems

Lecture 3, Jan 13 2016



Part I: How do we choose gears so they are strong enough?

1. Compute expected bending stresses (Wilfred Lewis + AGMA)

2. Compute *allowable* lifetime stress (with fatigue)

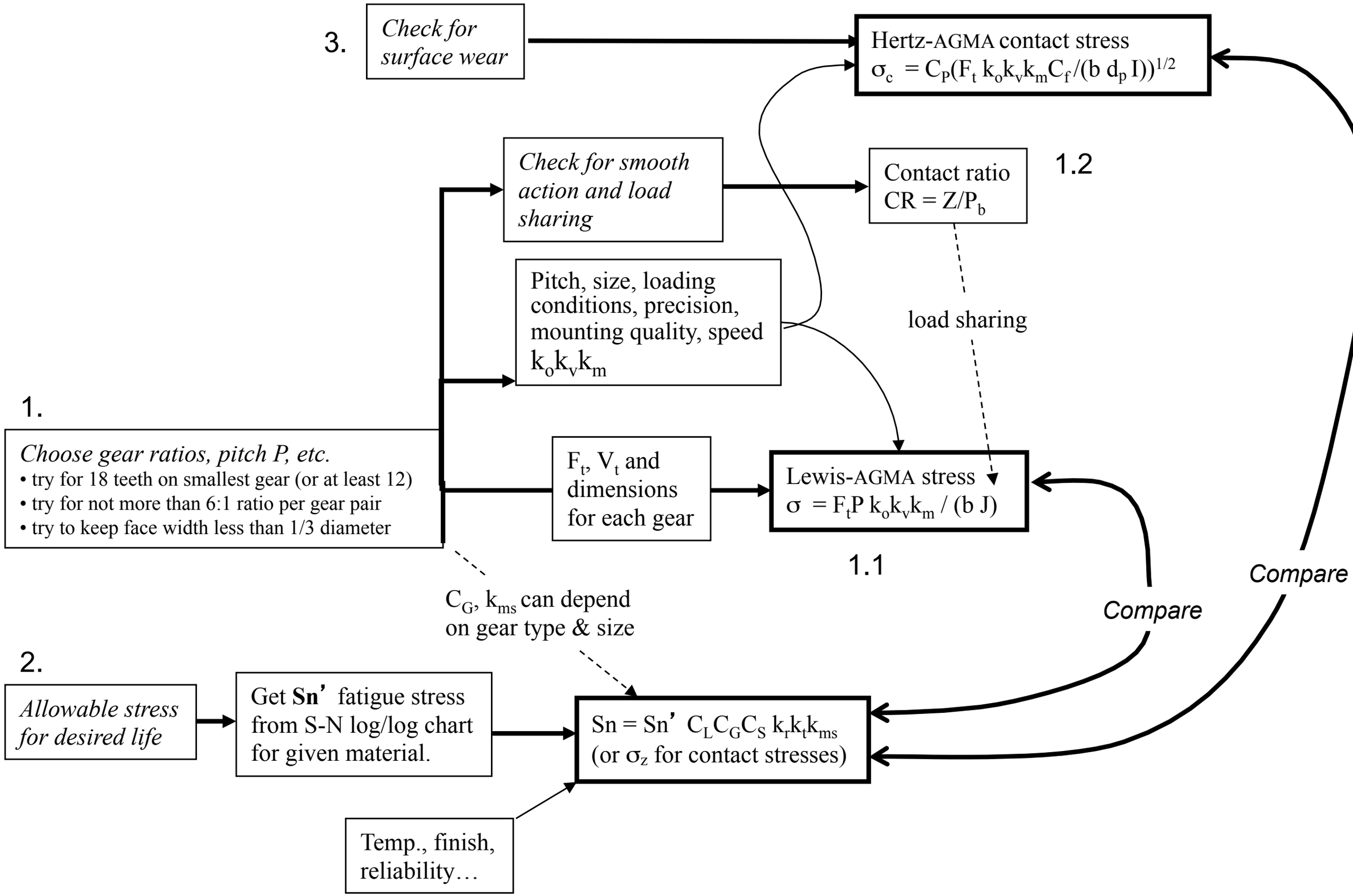
3. Compute contact stresses (Hertz + AGMA)

Part II: What is the state of the art in transmissions?

Example: Audi TT DSG (from ME310)

Gear design information flow v5 14Jan2014 -mrc

Flow Chart



Gear tooth stresses

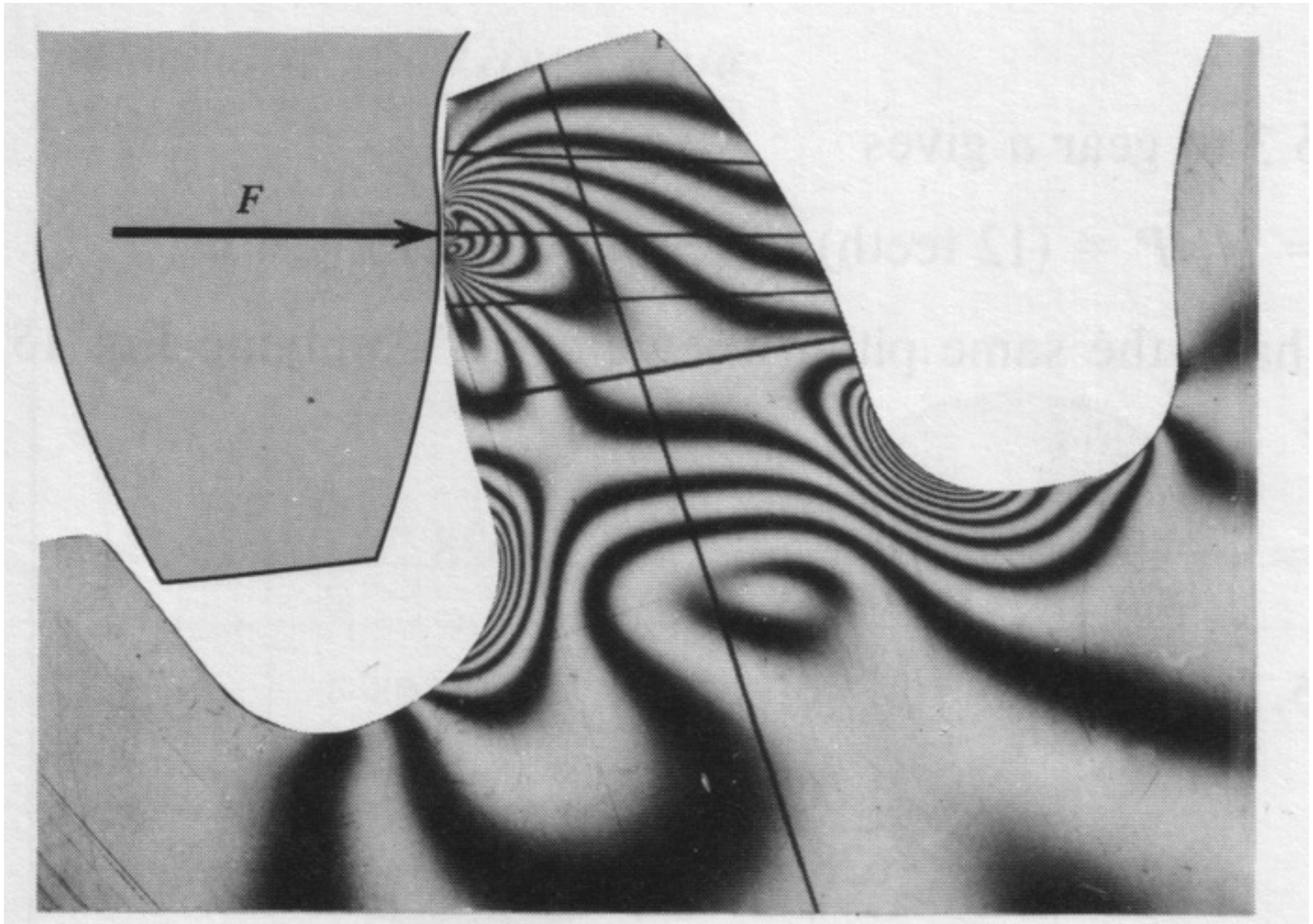


Figure 15.19 Photoelastic pattern of stresses in a spur gear tooth. (From T. J. Dolan and E. L. Broghammer, A Study of Stresses in Gear Tooth Fillets, Proc. 14th Eastern Photoelasticity Conf., PE December 1941.)

Allowable stress vs cycles

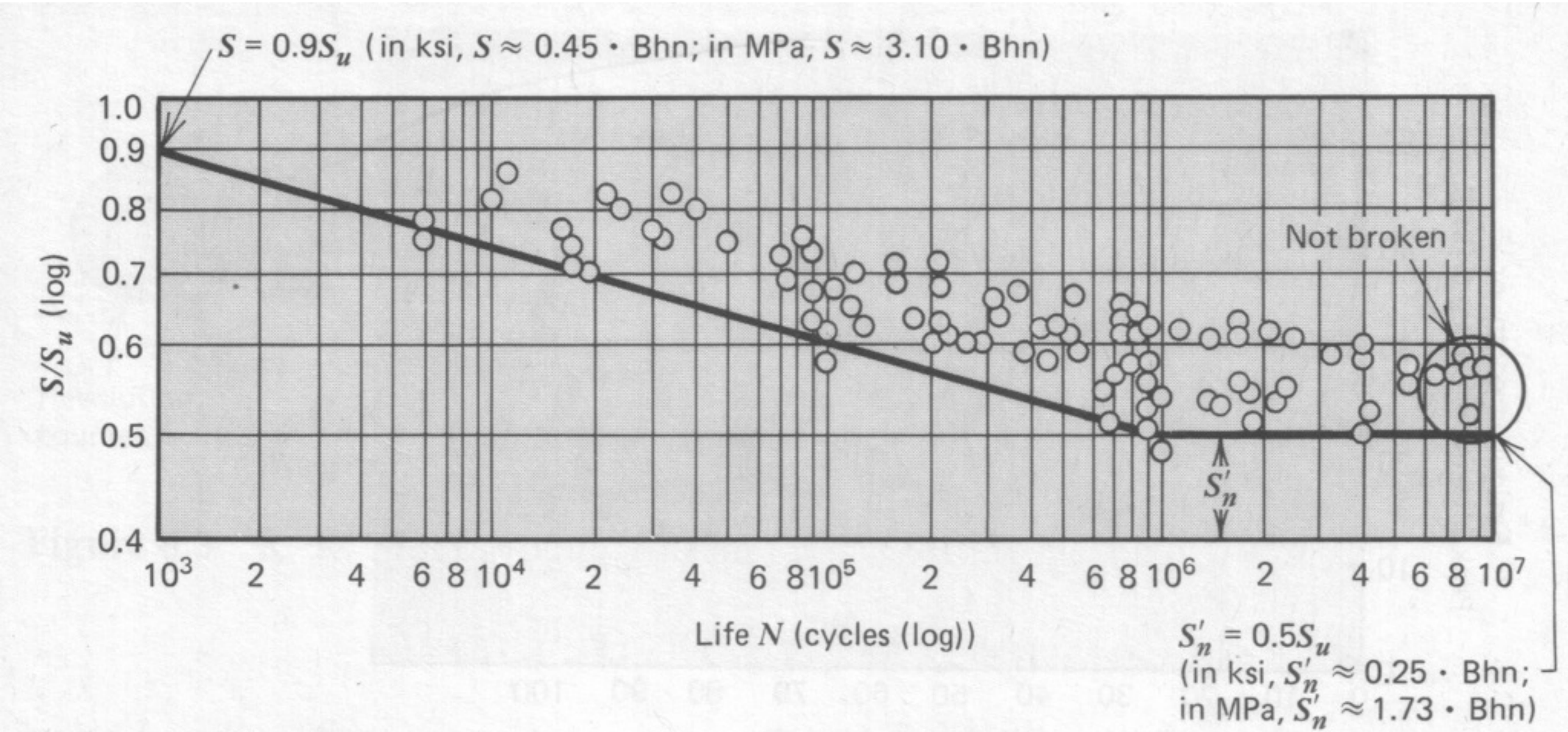


Figure 8.5 Generalized S–N curve for wrought steel with superimposed data points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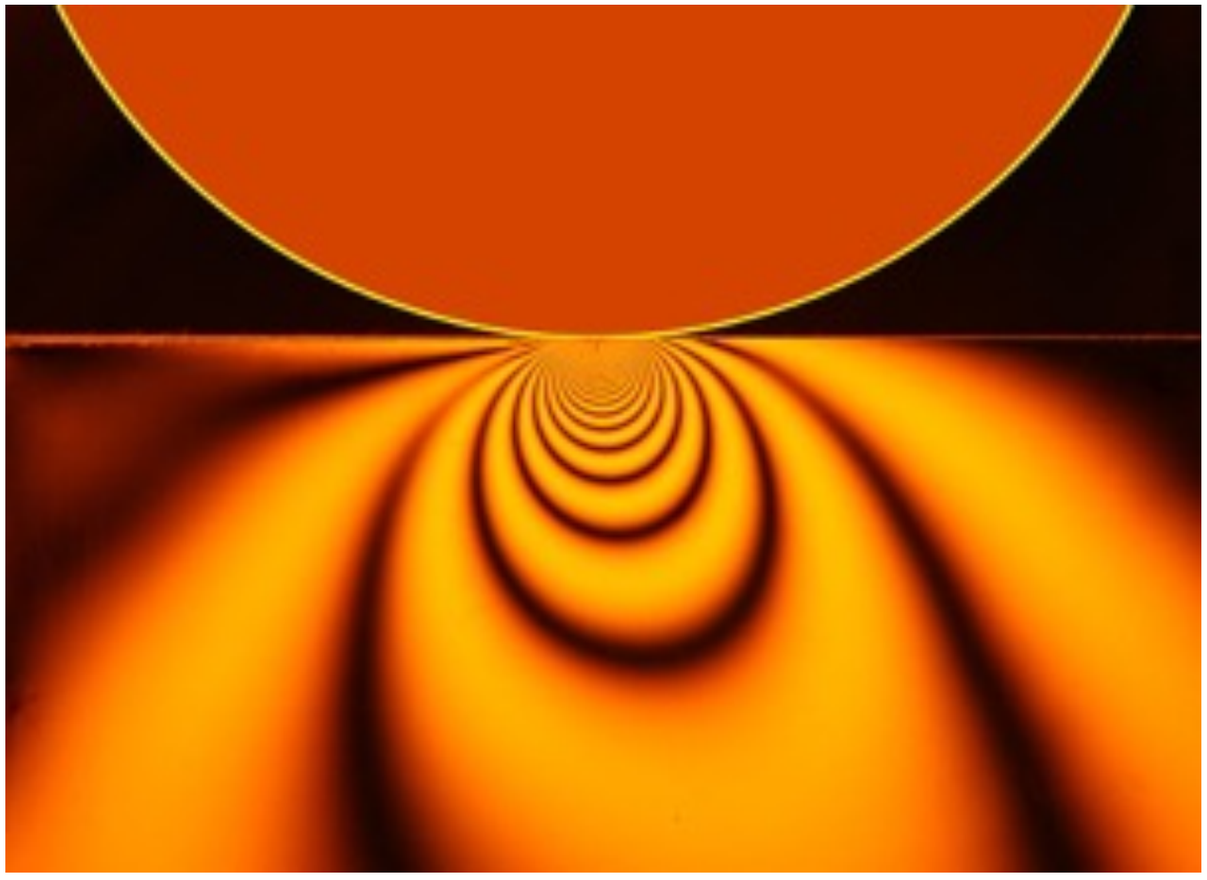
AGMA allowable lifetime stress

$$Sn = Sn' \cdot C_L \cdot C_G \cdot C_S \cdot k_r \cdot k_t \cdot k_{ms}$$

where:
Sn' = endurance limit from the chart
C_L = load factor (1.0 for bending)
C_G = gradient factor ~ crack size vs part size
C_S = surface finish effects
k_r = reliability factor (0.7 to 1.0)
k_t = temperature effects
k_{ms} = mean stress +/- or + only?

Contact stress

Whenever you bring two elastic, rounded bodies together
Case of cylinder/cylinder contact:



Classical solution from Hertz
in the 1880s

Maximum pressure (stress) goes as

$$p_0 = \left(\frac{E^* F}{\pi L R}\right)^{1/2}$$

Where F = force, E* = effective modulus of elasticity, L is length (here face width, b) and R is the effective curvature:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

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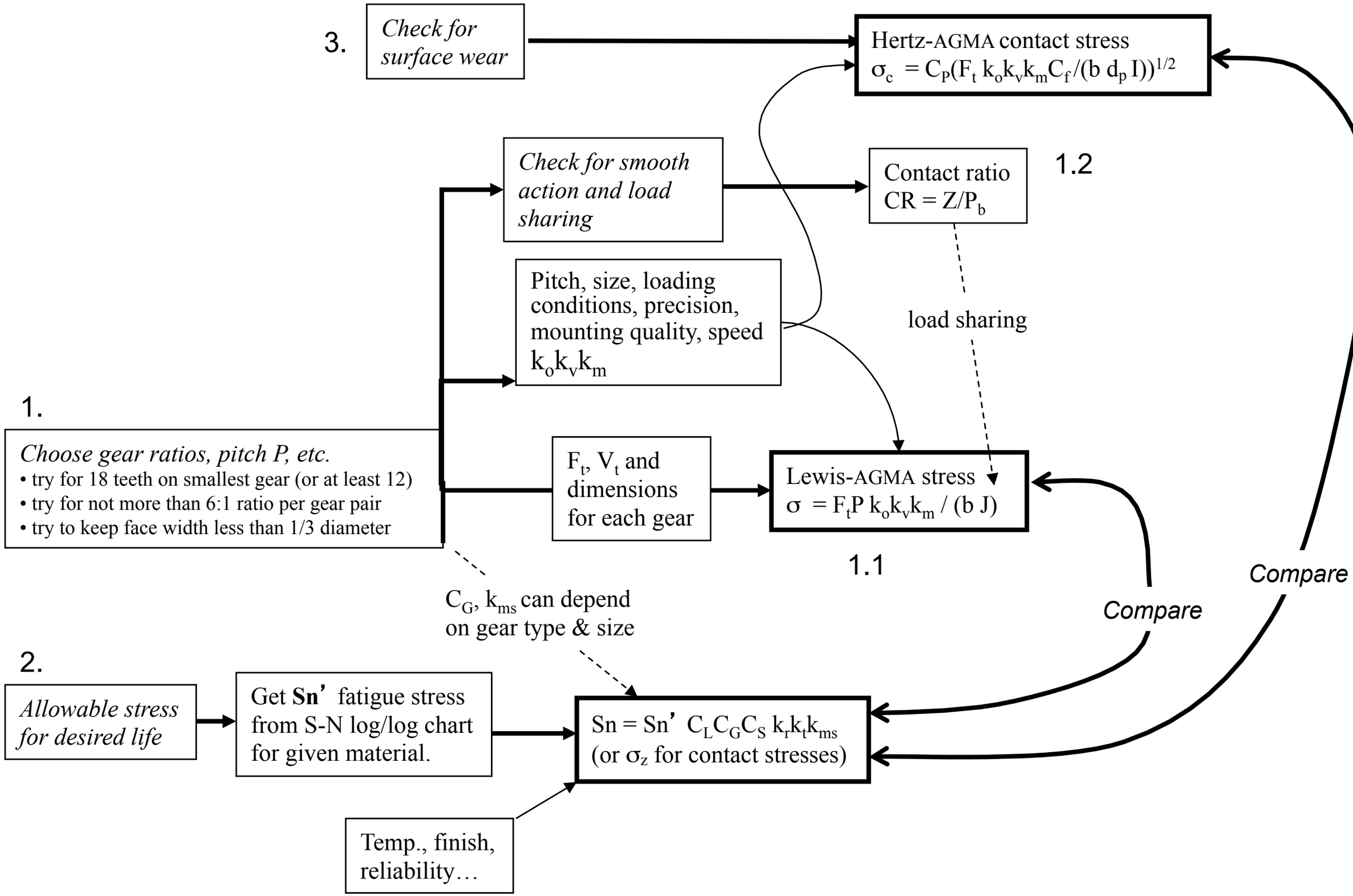
Flow Chart



AGMA contact stress

$$\sigma_c = C_p[C_f \cdot F_t \cdot K_o \cdot K_v \cdot K_m/(d_p \cdot b \cdot I)]^{1/2}$$

where:

C_p = elastic constant of material

C_f = relative hardness of each gear (1.0 if same)

F_t = tangential tooth force

K_o = overload factor (same as for Lewis bending)

K_v = velocity factor (same as for Lewis bending)

K_m = mounting factor (same as for Lewis bending)

d_p = temperature effects

b = mean stress +/- or + only?

I = geometry factor (see notes)

Compare to *allowable* contact stress σ_z

(higher than allowable bending stresses)

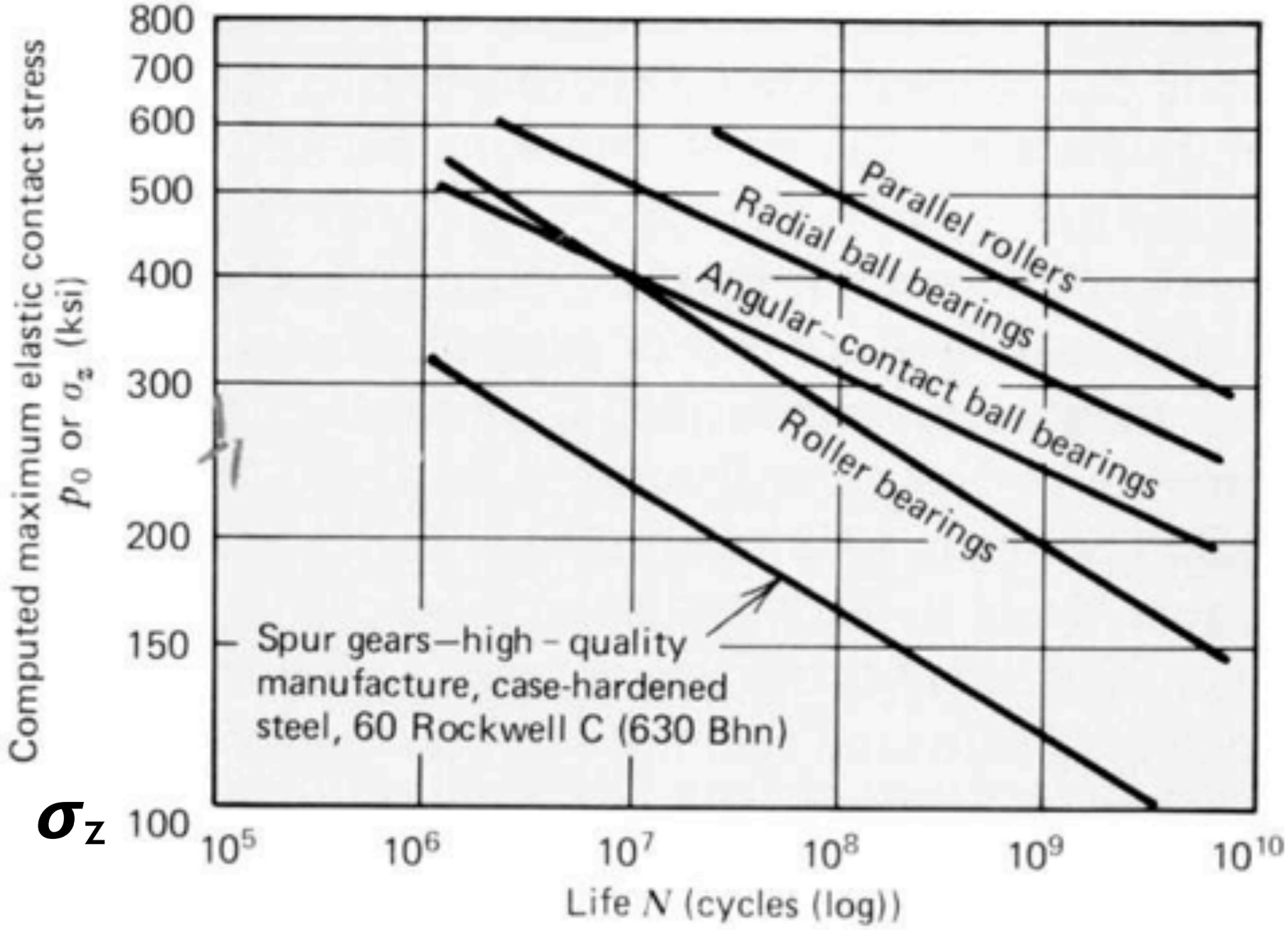


Figure 9.21 Average S–N curves for contact stresses—rollers, bearings, and spur gears, 10 percent failure probability [7].

Links

- Dislocations: http://www.kochmann.caltech.edu/research_animations.html
- Fatigue notes: http://www.sv.vt.edu/classes/MSE2094_NoteBook/97ClassProj/anal/kelly/fatigue.html
- Feynman on gears: http://bdml.stanford.edu/Main/FeynmanGears

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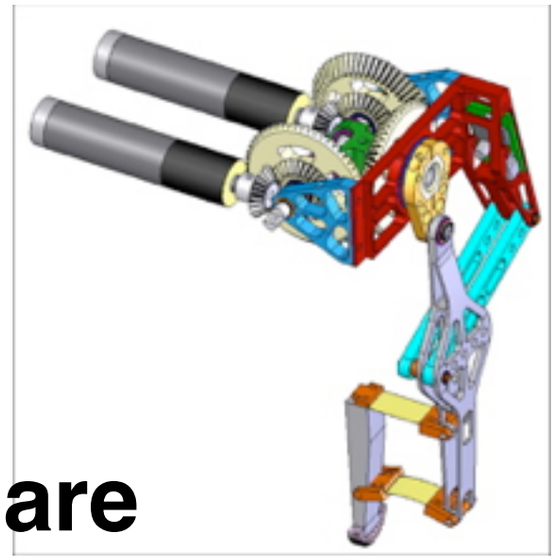

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