INTRODUCTION TO FAILURE PREVENTION

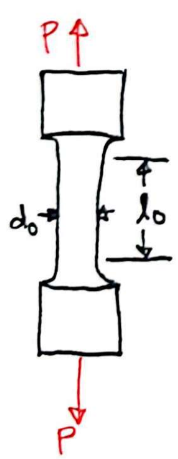
HOW MACHINE COMPONENTS FAIL

- MACHINE COMPONENTS CAN FAIL DUE TO STATIC OR VARIABLE LOADING:
  - ↳ **STATIC LOADS** ARE STATIONARY FORCES OR COUPLES APPLIED TO A MEMBER
  - ↳ **VARIABLE LOADS** CAN LEAD TO FATIGUE FAILURE, WHICH OCCURS WHEN A CRACK INITIATES & GROWS ~~AFTER~~ WHEN BEING SUBJECTED TO MANY CYCLES OF STRESS.

WE WILL DISCUSS STATIC LOADING THIS WEEK & VARIABLE LOADING NEXT.

- UNDER STATIC LOADS, COMPONENT MATERIALS CAN BEHAVE IN A DUCTILE OR BRITTLE MANNER.
  - ↳ **DUCTILE MATERIALS** CAN UNDERGO SIGNIFICANT PLASTIC DEFORMATION BEFORE FRACTURING. (e.g. STEEL, ALUMINUM, COPPER)
  - ↳ **BRITTLE MATERIALS** FRACTURE WITH LITTLE TO NO PLASTIC DEFORMATION. (e.g. GLASS, CERAMIC, CAST IRON)

STRESS-STRAIN RELATIONSHIPS FROM THE TENSILE TEST



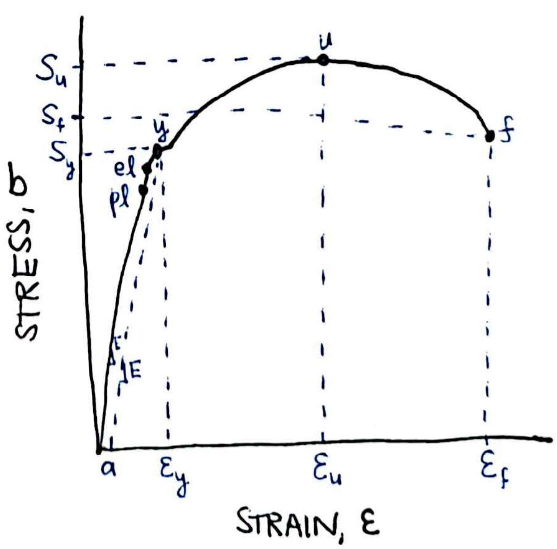
$$A_0 = \frac{1}{4}\pi d_0^2$$

STRESS:

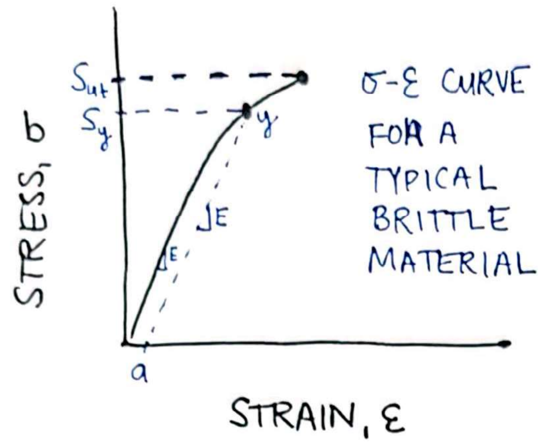
$$\sigma = \frac{P}{A_0}$$

STRAIN:

$$\varepsilon = \frac{l - l_0}{l_0}$$



σ-ε CURVE FOR A TYPICAL DUCTILE MATERIAL

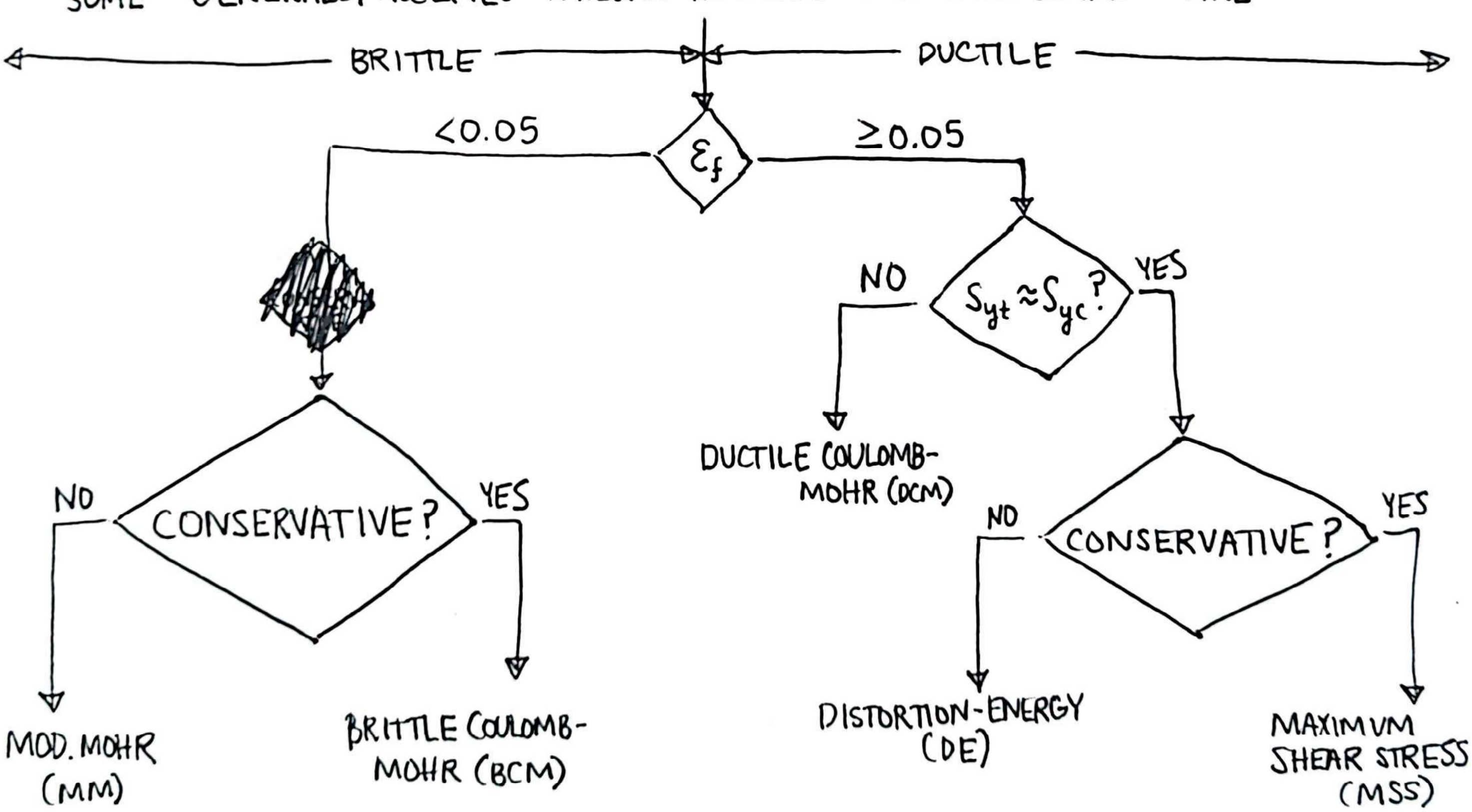


- POINT *pl* IS CALLED THE **PROPORTIONAL LIMIT.** THIS IS WHERE THE σ-ε CURVE BEGINS TO DEVIATE FROM A STRAIGHT LINE.
- POINT *el* IS CALLED THE **ELASTIC LIMIT.** AFTER THIS POINT, THE MATERIAL WILL BEGIN TO TAKE ON A PERMANENT SET.
- POINT y IS THE **YIELD POINT,** AND S_y IS THE CORRESPONDING **YIELD STRENGTH.**
  - ↳ THIS IS OFTEN DEFINED BY USING AN **OFFSET METHOD** BY DRAWING LINE ay WITH SLOPE E. a IS USUALLY DEFINED AS 0.2% STRAIN ($\varepsilon = 0.002$).
- POINT u IS THE **ULTIMATE POINT,** AND S_{ut} IS THE CORRESPONDING **ULTIMATE STRENGTH.** THIS IS THE MAX. σ THE MAT'L CAN WITHSTAND.
- POINT f IS THE **FRACTURE LIMIT,** AND S_f IS THE CORRESPONDING **FRACTURE STRESS.**

* A NOTE ABOUT YOUNG'S MODULUS (E):
E IS VERY NEARLY CONSTANT FOR A GIVEN TYPE OF MATERIAL (e.g. STEEL, ALUMINUM, COPPER) REGARDLESS OF HEAT TREATMENT, CARBON CONTENT, OR ALLOYING. (THOSE THINGS DO USUALLY AFFECT S_y AND S_{ut}.)

FAILURE THEORIES

SOME GENERALLY ACCEPTED FAILURE THEORIES FOR STATIC LOADING ARE:



MAXIMUM-SHEAR-STRESS THEORY FOR DUCTILE MATERIALS

THE MAXIMUM-SHEAR-STRESS (MSS) THEORY PREDICTS THAT YIELDING BEGINS WHEN THE MAXIMUM SHEAR STRESS IN ANY ELEMENT EQUALS OR EXCEEDS THE MAXIMUM SHEAR STRESS IN A TENSION-TEST SPECIMEN OF THE SAME MATERIAL WHEN THAT SPECIMEN BEGINS TO YIELD. (ALSO KNOWN AS THE TRESCA OR GUEST THEORY)

THE FAILURE CRITERION FOR THE MSS THEORY IS:

$$n = \frac{S_y}{\sigma_1 - \sigma_3} = \frac{S_y}{2\tau_{max}}$$

where n = SAFETY FACTOR. REMEMBER, WHEN $n=1$ FAILURE IS PREDICTED.

and $\sigma_1 \geq \sigma_2 \geq \sigma_3$ ARE THE ORDERED PRINCIPAL STRESSES.

FOR A PLANE STRESS STATE, ONE OF THE PRINCIPAL STRESSES IS ZERO. THERE ARE 3 POSSIBILITIES:

1. $\sigma_A \geq \sigma_B \geq 0$ $(\sigma_1 \geq \sigma_2 \geq 0)$

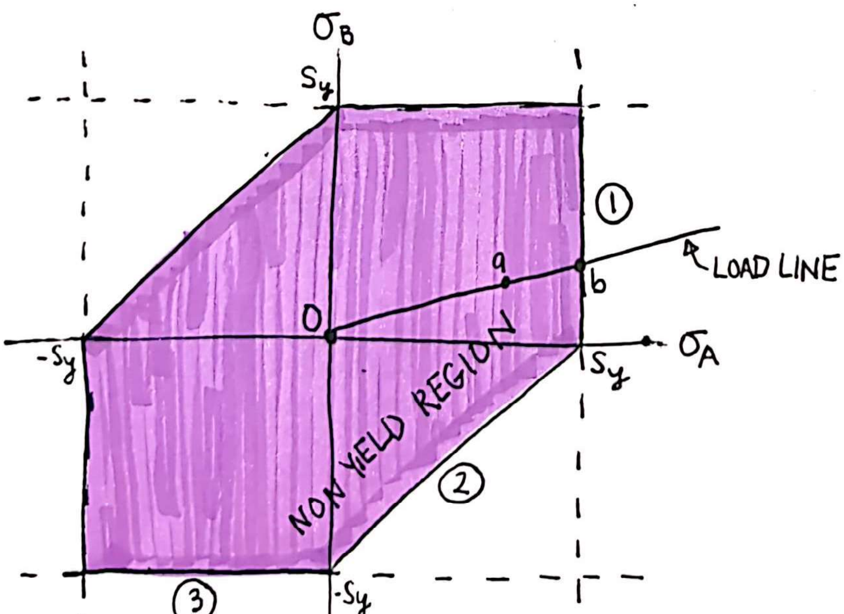
   THEN, THE MSS FAILURE CRITERION IS $\sigma_A \geq S_y$ $\left(n = \frac{S_y}{\sigma_A} = \frac{S_y}{\sigma_1}\right)$

2. $\sigma_A \geq 0 \geq \sigma_B$ $(\sigma_1 \geq 0 \geq \sigma_3)$

   THEN, THE MSS FAILURE CRITERION IS $\sigma_A - \sigma_B \geq S_y$ $\left(n = \frac{S_y}{\sigma_1 - \sigma_3} = \frac{S_y}{\sigma_A - \sigma_B}\right)$

3. $0 \geq \sigma_A \geq \sigma_B$ $(0 \geq \sigma_2 \geq \sigma_3)$

   THEN, THE MSS FAILURE CRITERION IS $\sigma_B \leq -S_y$ $\left(n = \frac{S_y}{-\sigma_3} = \frac{S_y}{-\sigma_B}\right)$



*IF POINT a REPRESENTS THE STRESS STATE OF A CRITICAL STRESS ELEMENT OF A MEMBER, AND POINT b REPRESENTS THE STRESS STATE OF THAT SAME ELEMENT AT THE CRITICAL LOAD, THEN THE FACTOR OF SAFETY GUARDING AGAINST YIELD AT POINT a IS

$$n = \frac{Ob}{Oa}$$