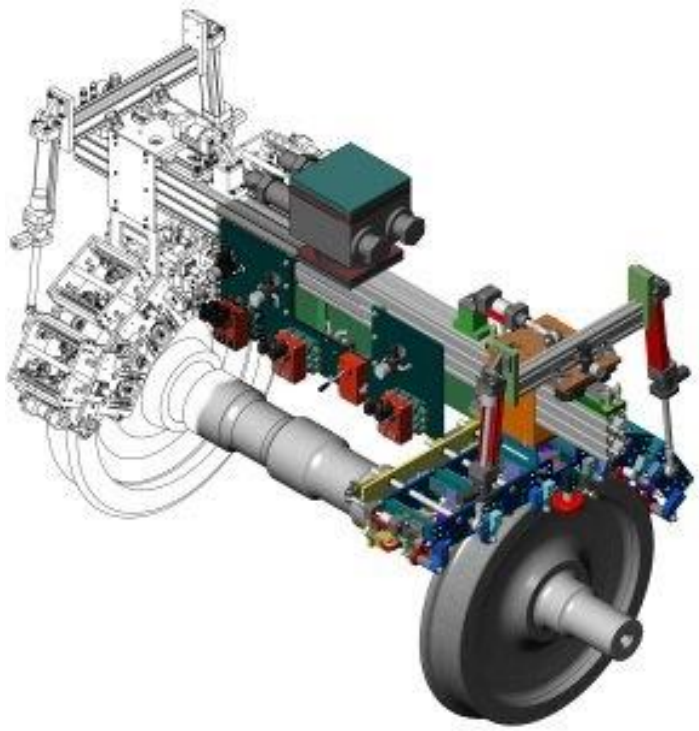


Modul 01
Review tentang Sifat Material

01.01. Pendahuluan

MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

Modul 01. Review tentang Sifat Material

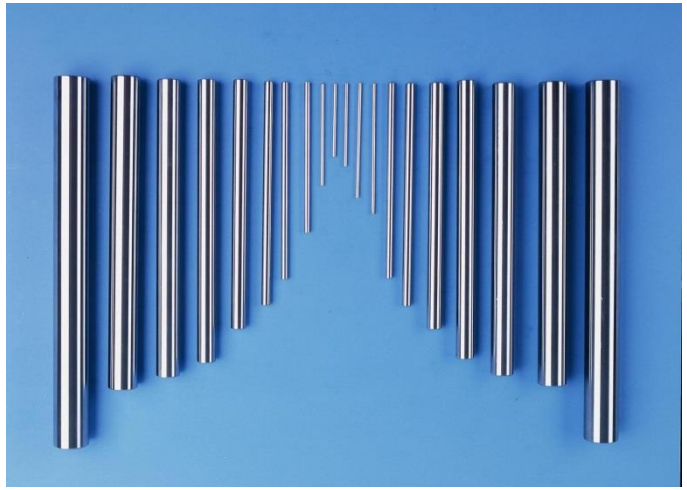
Segmen 1	Pendahuluan
Segmen 2	Sifat Mekanik dan Uji Material
Segmen 3	Uji Tarik
Segmen 4	Uji Tekan
Segmen 5	Uji Lentur
Segmen 6	Uji Puntir
Segmen 7	Uji Lelah
Segmen 8	Uji Impak
Segmen 9	Uji Laju Regangan Tinggi
Segmen 10	Uji Kekerasan
Segmen 11	Pemilihan Material

Desain Sebuah Komponen

Mana yang harus dipilih terlebih dahulu?

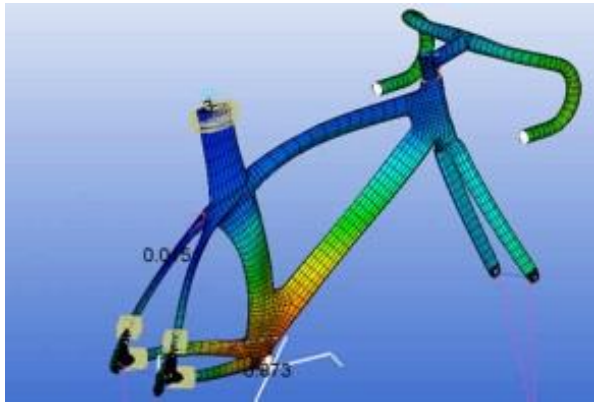
Pemilihan Jenis Material

Pemilihan Ukuran



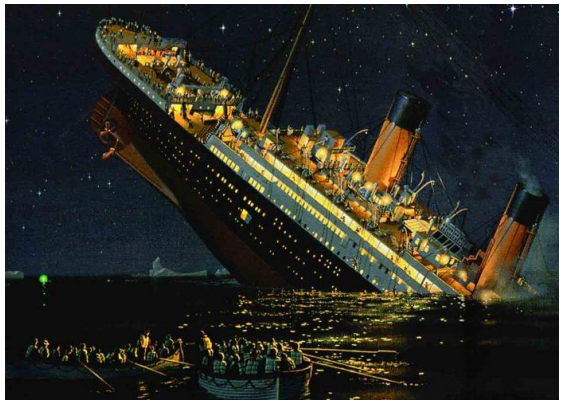
Desain Komponen –

Faktor yg dipertimbangkan

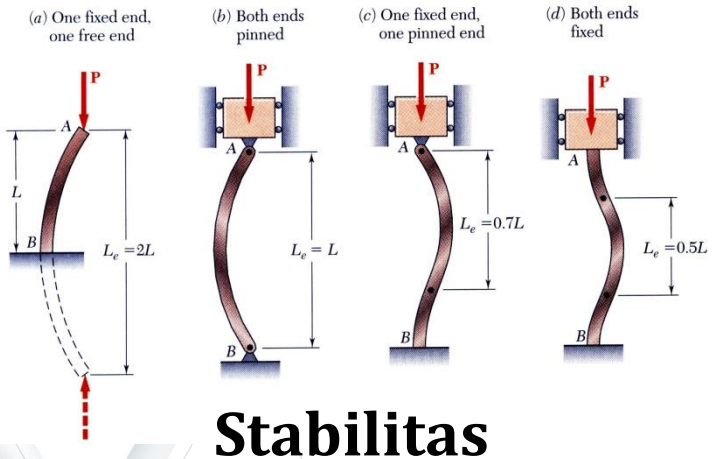


Tegangan - Regangan

Korosi



Beban Impak

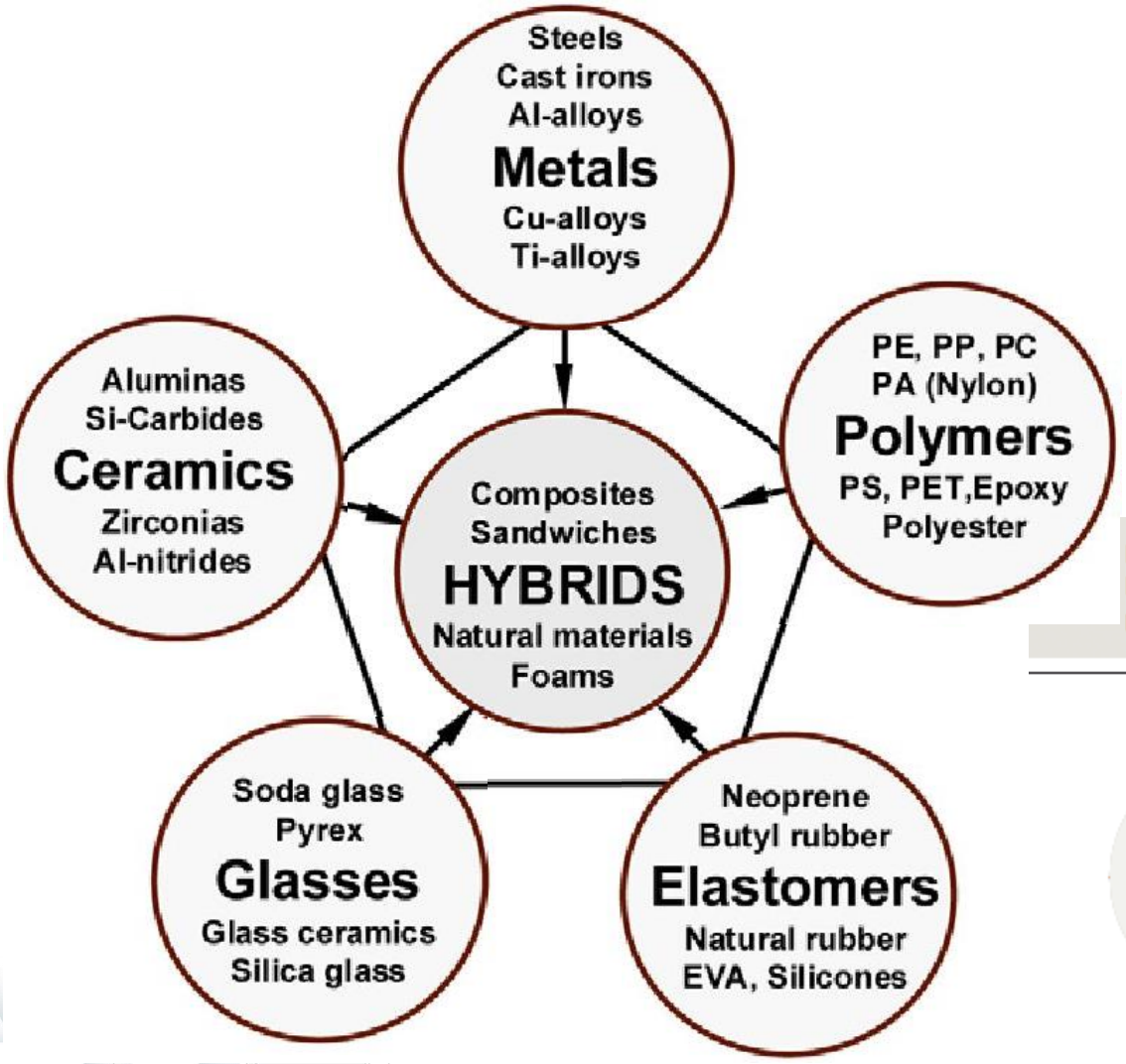


Stabilitas

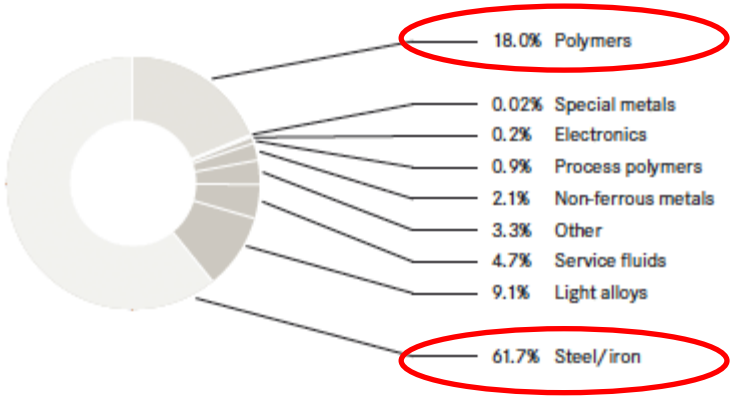
Konduktifitas Termal

Kekakuan

Pengelompokan Material



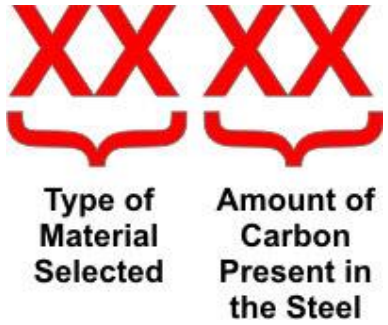
Material composition of the Daimler passenger car fleet
Distribution over the number of Mercedes-Benz and smart passenger cars sold in Europe in 2009



More than half of the vehicle weight (61.7 percent) is accounted for by steel/iron, followed by polymers with 18 percent and lightweight metals as the third-largest fraction (9.1 percent).

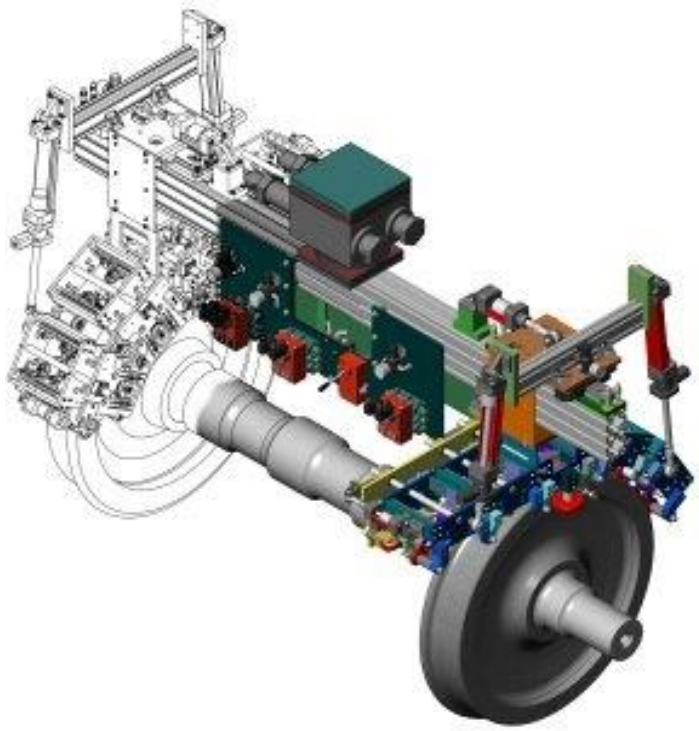
Sistem Penomoran Material

AISI/SAE Steel Designation System



SAE designation	Type
1xxx	Carbon steels
2xxx	Nickel steels
3xxx	Nickel-chromium steels
4xxx	Molybdenum steels
5xxx	Chromium steels
6xxx	Chromium-vanadium steels
7xxx	Tungsten steels
8xxx	Nickel-chromium-vanadium steels
9xxx	Silicon-manganese steels

AISI Steel		Specifications
Carbon Steel	10XX	Plain carbon steel , Mn 1.00% max
	11XX	Resulfurized free cutting
	12XX	Resulfurized - Rephosphorized free cutting
	15XX	Plain carbon steel, Mn 1.00-1.65%
Manganese Steel	13XX	Mn 1.75%
Nickel Steel	23XX	Ni 3.50%
	25XX	Ni 5.00%
Nickel Chromium Steel	31XX	Ni 1.25%, Cr 0.65-0.80%
	32XX	Ni 1.75%, Cr 1.07%
	33XX	Ni 3.50%, Cr 1.50-1.57%
	34XX	Ni 3.00%, Cr 0.77%
Molybdenum Steel	40XX	Mo 0.20-0.25%
	44XX	Mo 0.40-0.52%



Modul 01
Review tentang Sifat Material

01.02. Sifat Mekanik dan Uji Material

MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

Sifat Mekanik dari Material

- Sifat mekanis material dapat diperoleh dengan pengujian destruktif dari sampel dengan pembebanan terkontrol.
- The American Society for Testing and Materials (ASTM) mendefinisikan standar untuk benda uji dan prosedur uji untuk pengukuran sifat berbagai material.
  - ASTM E8 / E8M - Standard Test Methods for Tension Testing of Metallic Materials
  - ASTM D638 - Standard Test Method for Tensile Properties of Plastics
  - ASTM D3039 / D3039M - Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials

Sifat Mekanik dari Material

- **Kekuatan/Strength:**
  - Kekuatan Tarik/ Tensile Strength: Tegangan tarik maksimum yang dapat ditahan suatu material sebelum terjadinya kegagalan (MPa)
  - Kekuatan Tekan/ Compressive Strength: Tegangan tekan maksimum yang dapat ditahan suatu material sebelum terjadinya kegagalan (MPa)
  - Kekuatan Geser/ Shear Strength: Tegangan geser maksimum yang dapat ditahan suatu material sebelum terjadinya kegagalan (MPa)
  - Kekuatan Luluh/ Yield Strength: Tegangan saat material mulai luluh/mengalami deformasi permanen (MPa)

Sifat Mekanik dari Material

- **Modulus:**
  - Modulus Elastis/ Young Modulus, ***E***: Perbandingan linear antara tegangan terhadap regangan dari uji tarik (MPa)
  - Modulus Elastis Geser/ Shear Modulus (Modulus of Rigidity), ***G***: Perbandingan linear antara tegangan gesear terhadap regangan gesear dari uji puntir (MPa)
  - ModulusLentur /Flextural (Bending) Modulus, ***EI*** : Perbandingan tegangan terhadap regangan dalam deformasi lentur atau kecenderungan material untuk menekuk (MPa)

Sifat Mekanik dari Material

- Kekerasan / Hardness

  Kemampuan untuk menahan lekukan permukaan

- Poisson's Ratio

  Perbandingan regangan lateral terhadap regangan aksial

- Koefisien friksi/Coefficient of Friction

  Perbandingan antara gaya gesek dengan gaya normal yang menekan kedua benda

- Koefisien restitusi/Coefficient of restitution

  Perbandingan kecepatan setelah dan sebelum tumbukan, diambil di sepanjang garis tumbukan.

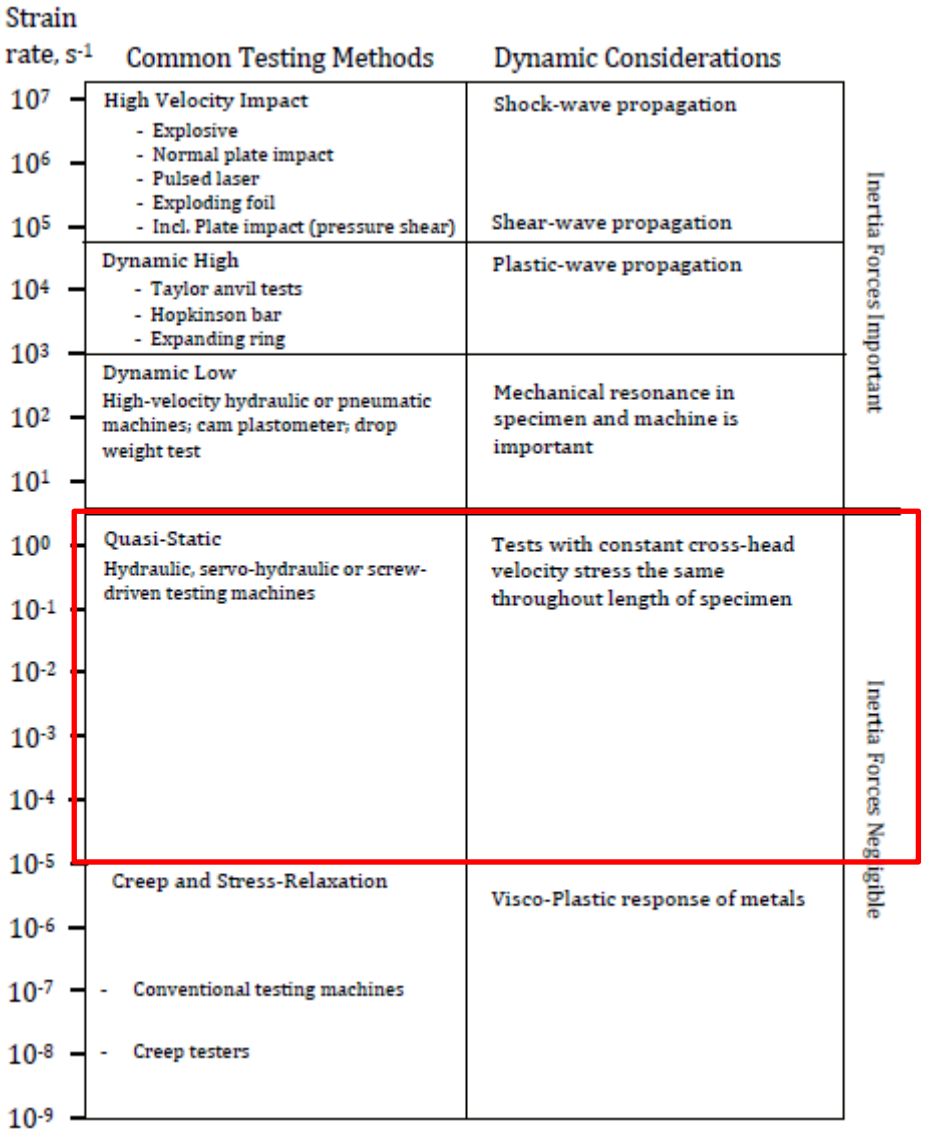
- Kekasaran permukaan/Surface Roughness

  Penyimpangan (arah normal) permukaan nyata dari permukaan idealnya.

Sifat Mekanik dari Material

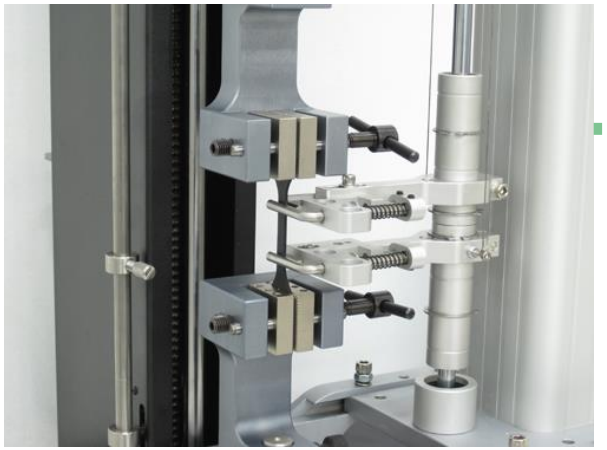
- Keuletan/Ductility: Kemampuan material untuk berubah bentuk di bawah beban tarik (%).
- Keplastisan/Plasticity: Kemampuan material untuk mengalami deformasi permanen
- Ketahanan/Resilience: Kemampuan suatu bahan untuk menyerap energi ketika dideformasi secara elastis (MPa).
- Ketangguhan/ Fracture Toughness: Energi yang diserap pada satuan luas sebelum material mengalami retak (J/m^2)
- Batas Lelah/ Fatigue Limit: Tegangan maksumum yang dapat ditahan material dibawah beban berulang (MPa)
- Creep: Deformasi lambat dan bertahap suatu benda sepanjang waktu

Pengujian Sifat Mekanik



- ❑ Uji Tarik/Tensile Testing
- ❑ Uji Tekan/Compression Testing
- ❑ Uji Puntir/Torsion Test
- ❑ Uji Lentur/Bending Test

Tension Test



Compression Test

Uji Sifat Mekanik

Bending Test

Torsion Test

Universal Testing Machine (UTM)

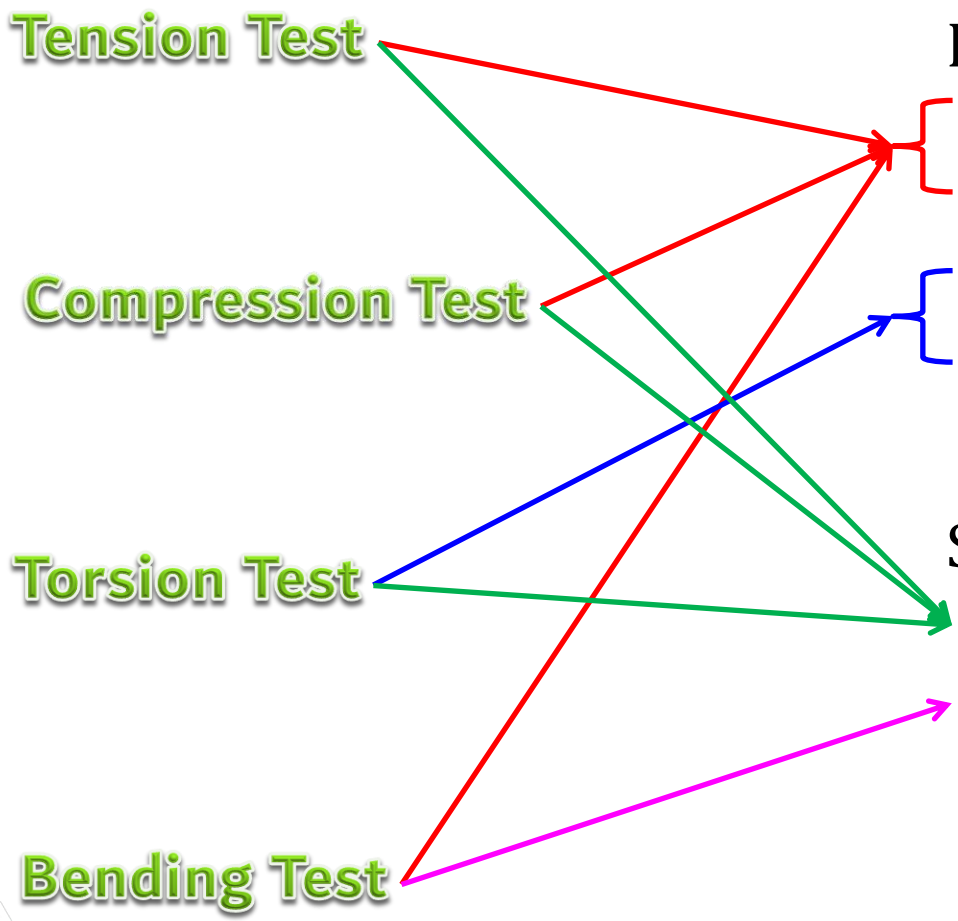
Tension Test

Compression Test

Bending Test

Sumber:
https://bit.ly/3lwflXy

Pengujian Sifat Mekanik

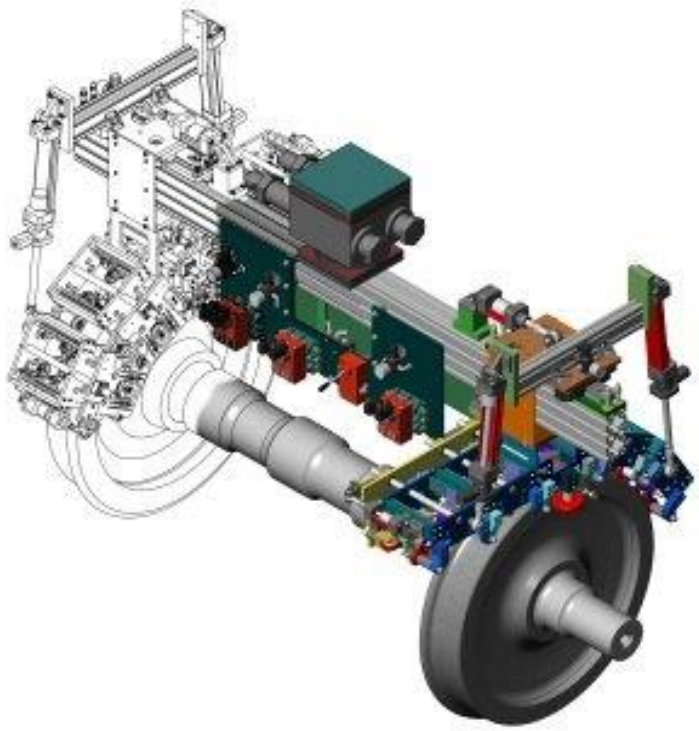


Parameter yg diukur:

- P: Beban, N
- d: Perpindahan, mm
- T: Torsi, Nm
- ϕ: Sudut puntir, rad

Sifat mekanik dicari:

- Kekuatan material/Materials Strength
- Kekakuan material/Materials Stiffness



Modul 01
Review tentang Sifat Material

01.03. Uji Tarik

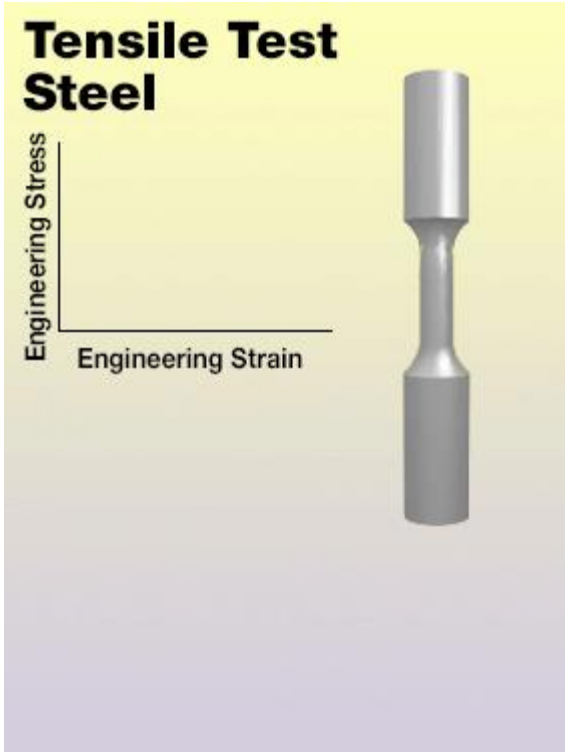
MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

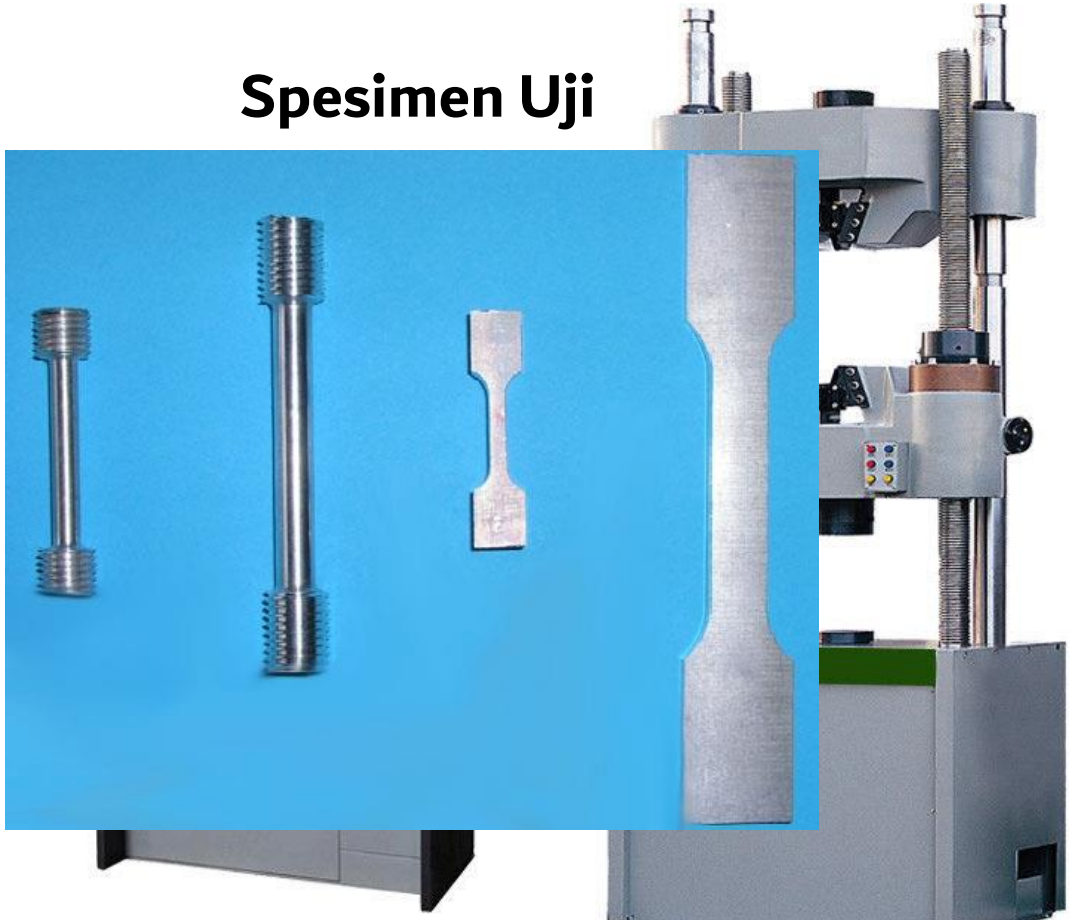
Uji Tarik/Tensile test

ASTM E8 / E8M - Standard Test Methods for **Tension Testing** of Metallic Materials

Mesin Uji

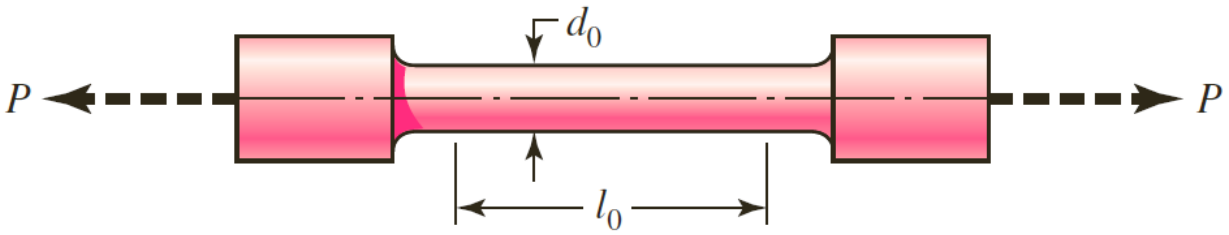


Spesimen Uji

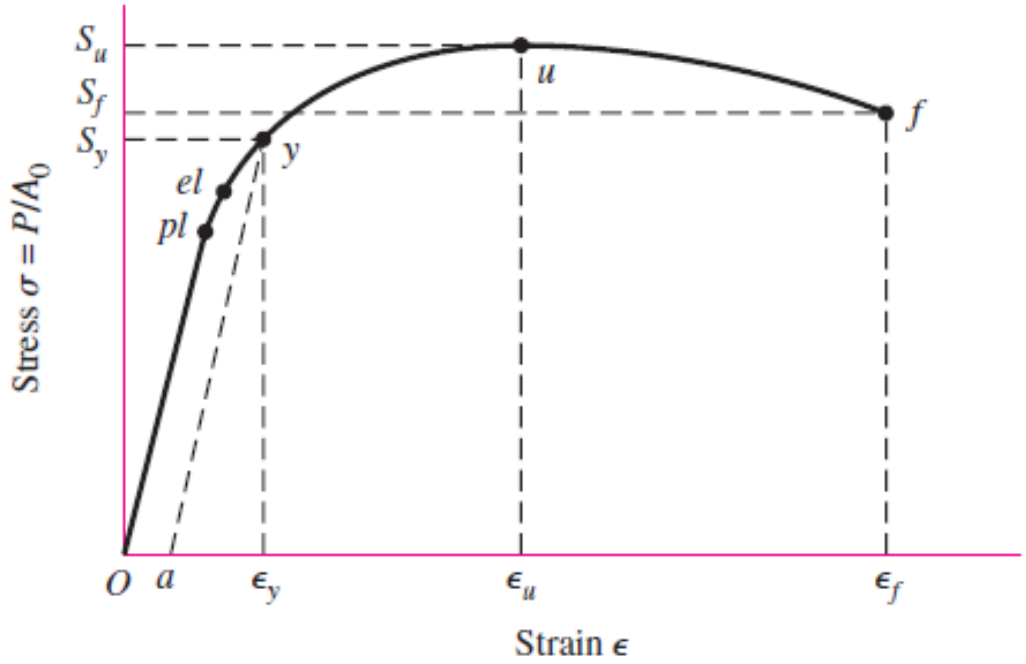


Sumber: http://upload.wikimedia.org/wikipedia/commons/7/71/Tensile_specimen-round_and_flat.jpg

Uji Tarik



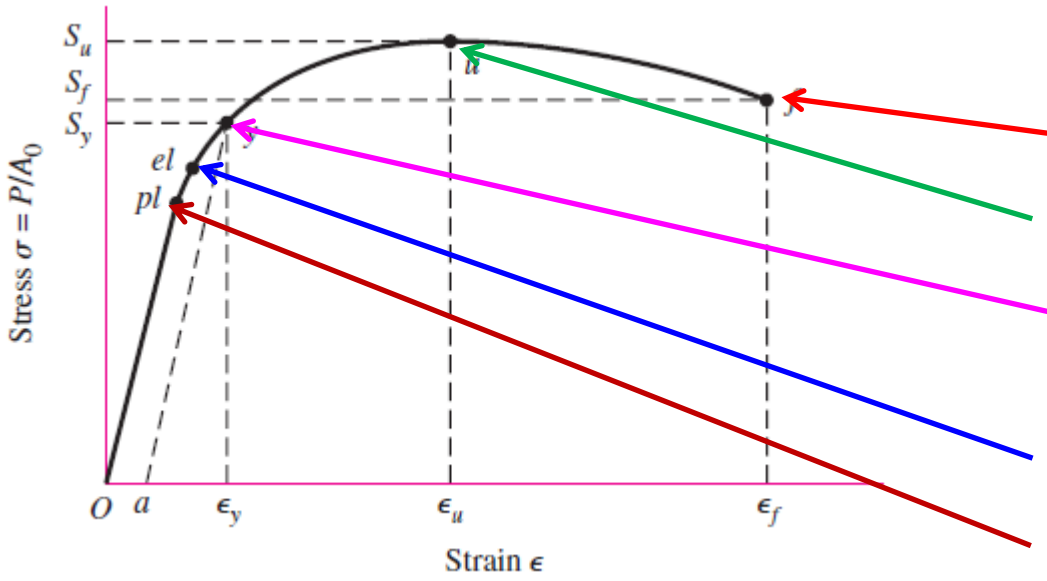
d_0 = 2.5, 6.25, and 12.5 mm & 0.505 in
l_0 = 10, 25, and 50 mm & 1 and 2 in.



Parameter yang diukur:

- ***P***: Beban, N ⟶ Sifat mekanik:
  - σ: tegangan, MPa $S = \frac{P}{A_0}$
- ***d***: Perpindahan, mm ⟶
  - ε: regangan, m/m $\epsilon = \frac{l - l_0}{l_0}$

Karakteristik Material Ulet



f: titik patah

u: kekuatan tarik/ultimate strength

y: titik luluh

a: offset = 0.002 (0.2%)

el: batas elastis

pl: batas proporsional

Tegangan

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

Regangan

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

Hukum Hooke

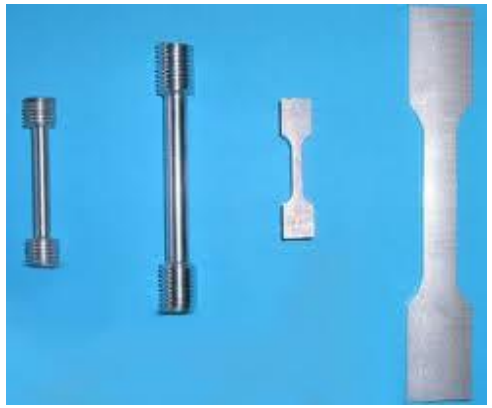
$$\sigma = E\varepsilon$$

E: Modulus of elasticity

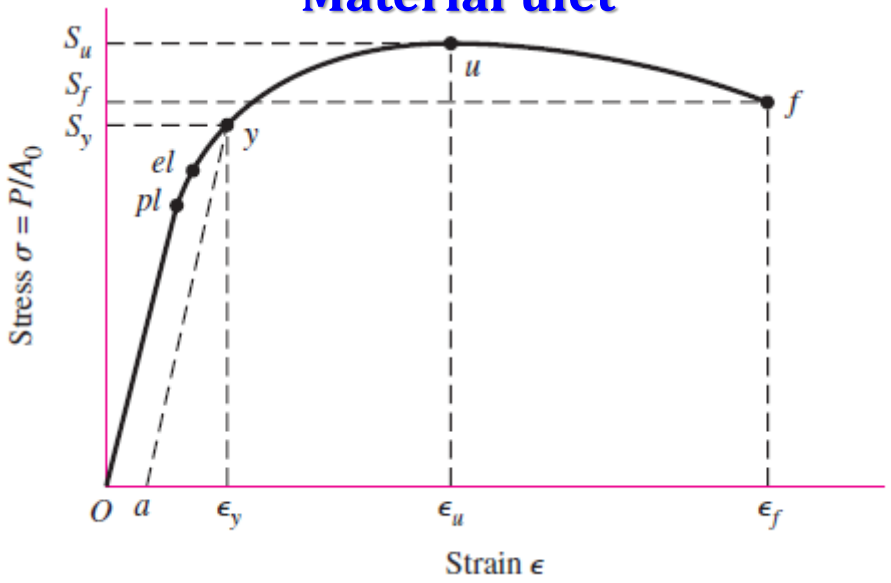
Young's Modulus

KEKUATAN/ STRENGTH, *S* **vs.** **TEGANGAN/ STRESS, σ**

Kekuatan dan Kekakuan Material

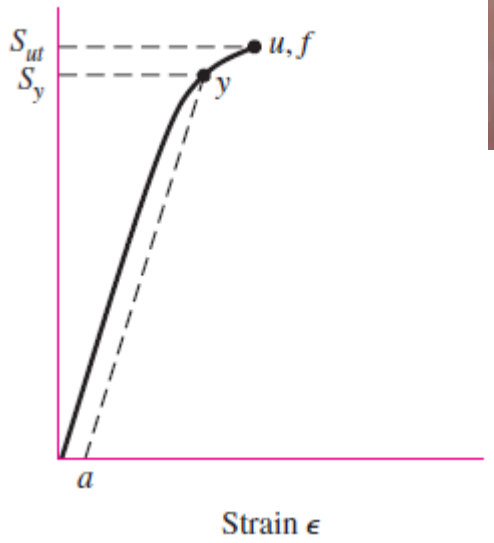


Material ulet

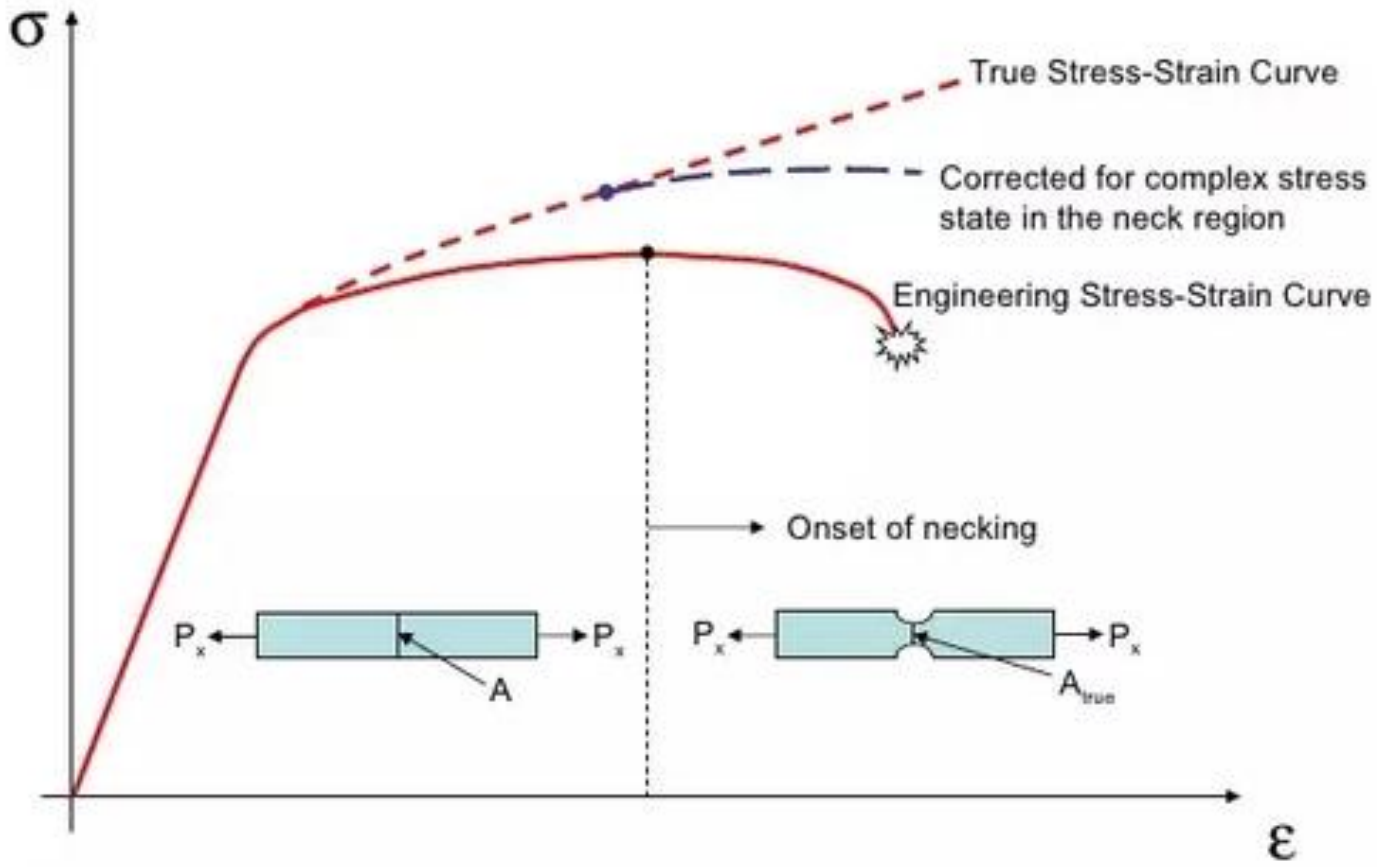


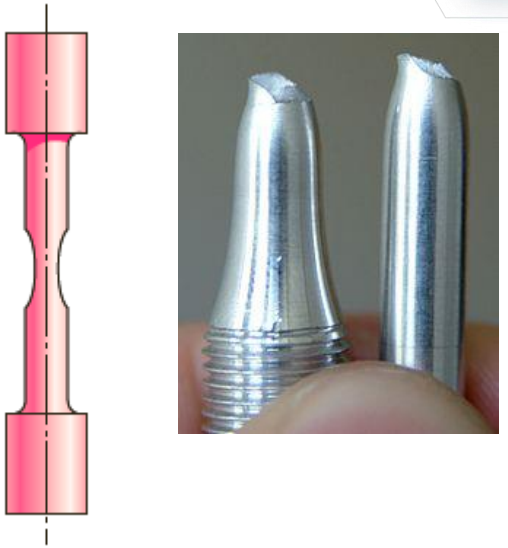
$\varepsilon_f = 5\%$

Material getas



Penciutan/ *Necking* pada spesimen





$$\sigma_t = \sigma(1+\varepsilon)$$

$$\varepsilon_t = \ln(1+\varepsilon)$$

Sifat Mekanik:

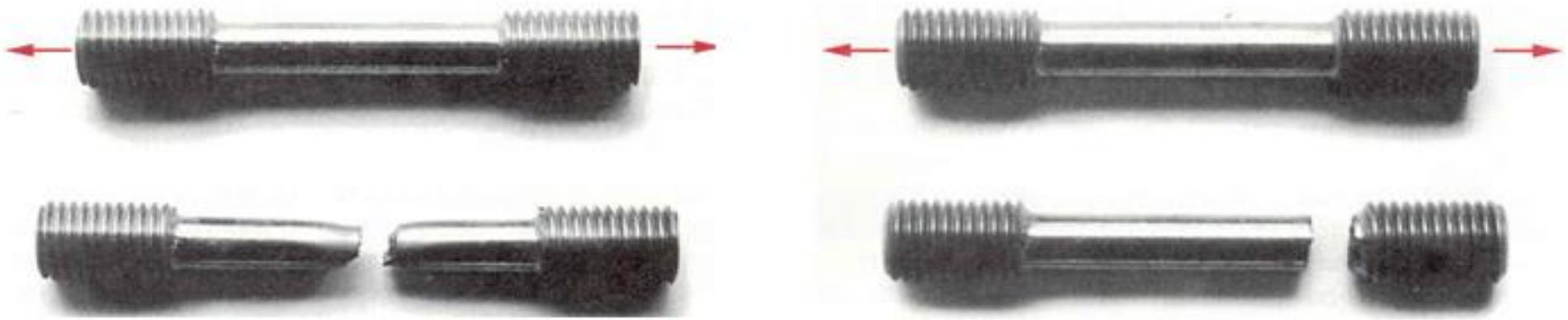
S_y S_{ut} E

% elongation

Sumber:
https://www.quora.com/Why-do-we-use-the-engineering-stress-strain-curve-if-the-true-stress-strain-curve-is-more-accurate

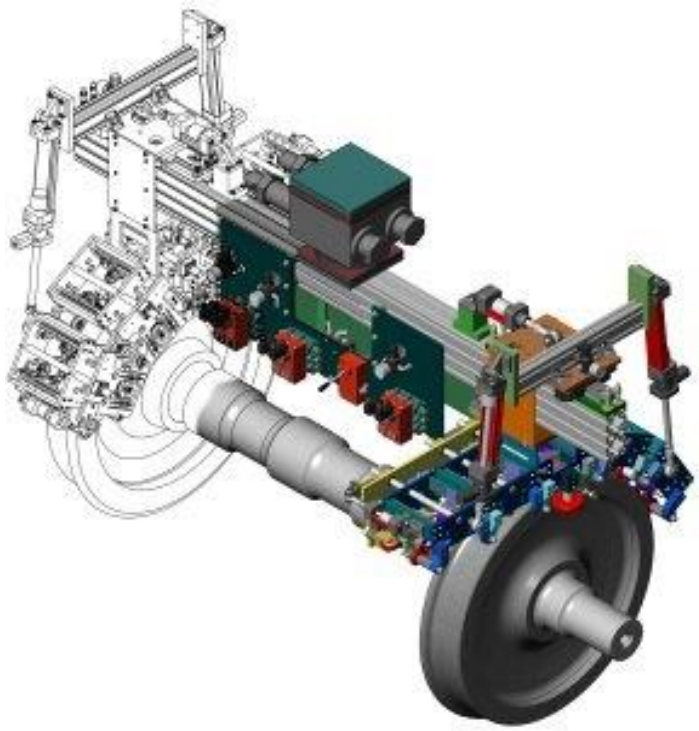
Keuletan dan Kegetasan

- Kecenderungan material untuk berubah bentuk secara signifikan sebelum patah terjadi adalah ukuran keuletannya.
- Tidak adanya deformasi signifikan sebelum patah terjadi disebut kegetasan.



(a) (b)

Tensile test specimen before and after failure (a) ductile steel, (b) brittle cast iron



Modul 01
Review tentang Sifat Material

01.04. Uji Tekan

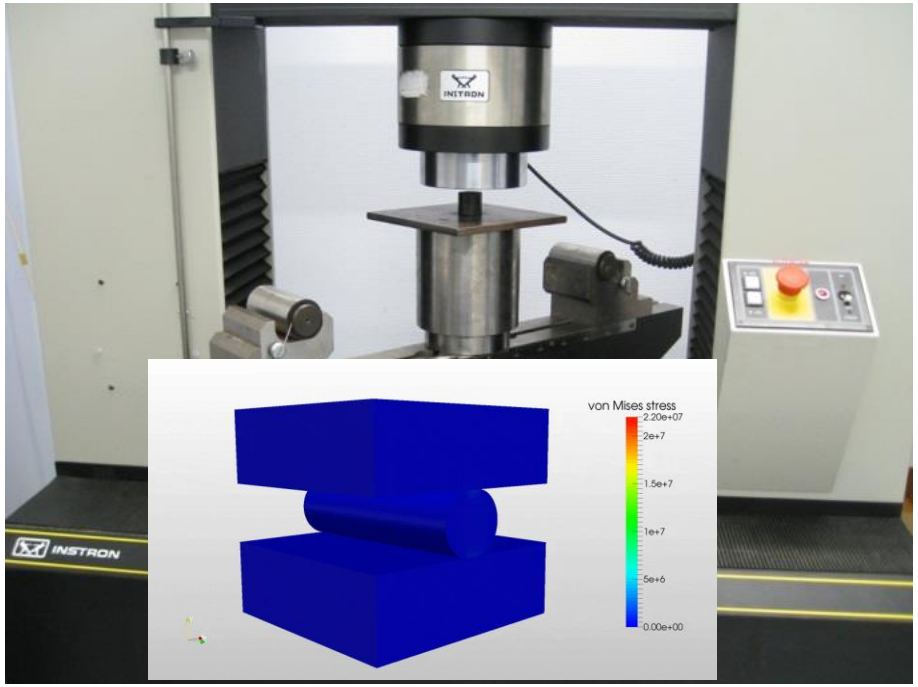
MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

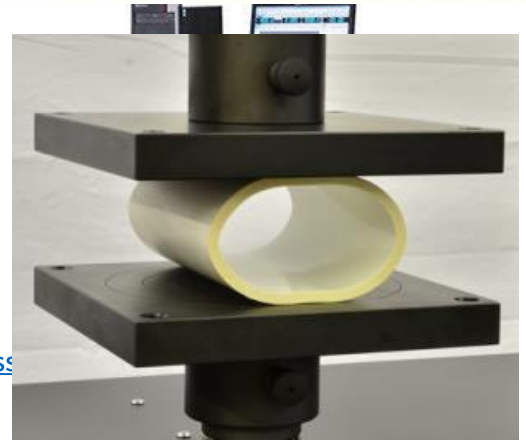
Uji Tekan

ASTM E9 - Standard Test Methods of **Compression Testing** of Metallic Materials at Room Temperature

Mesin Uji

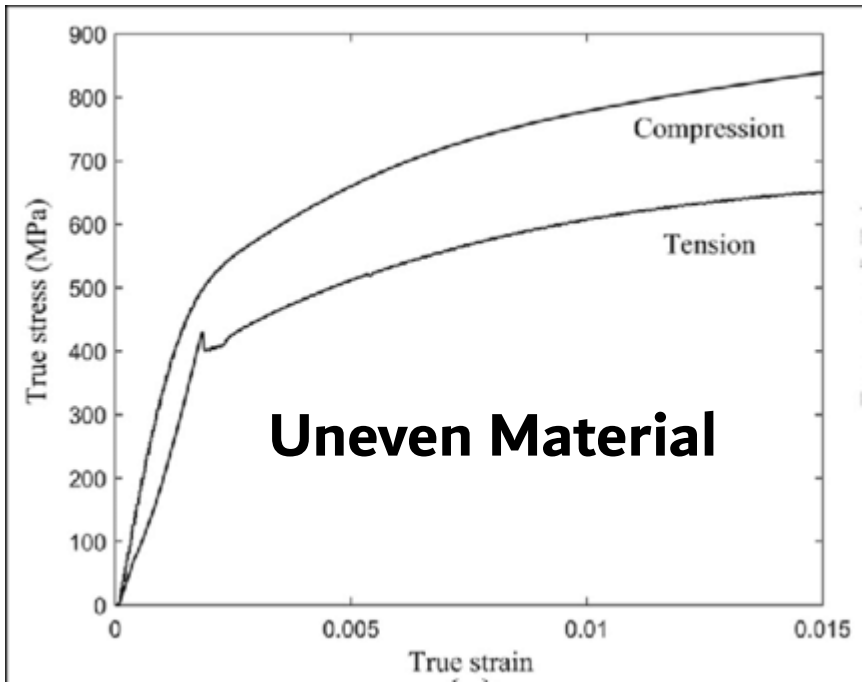


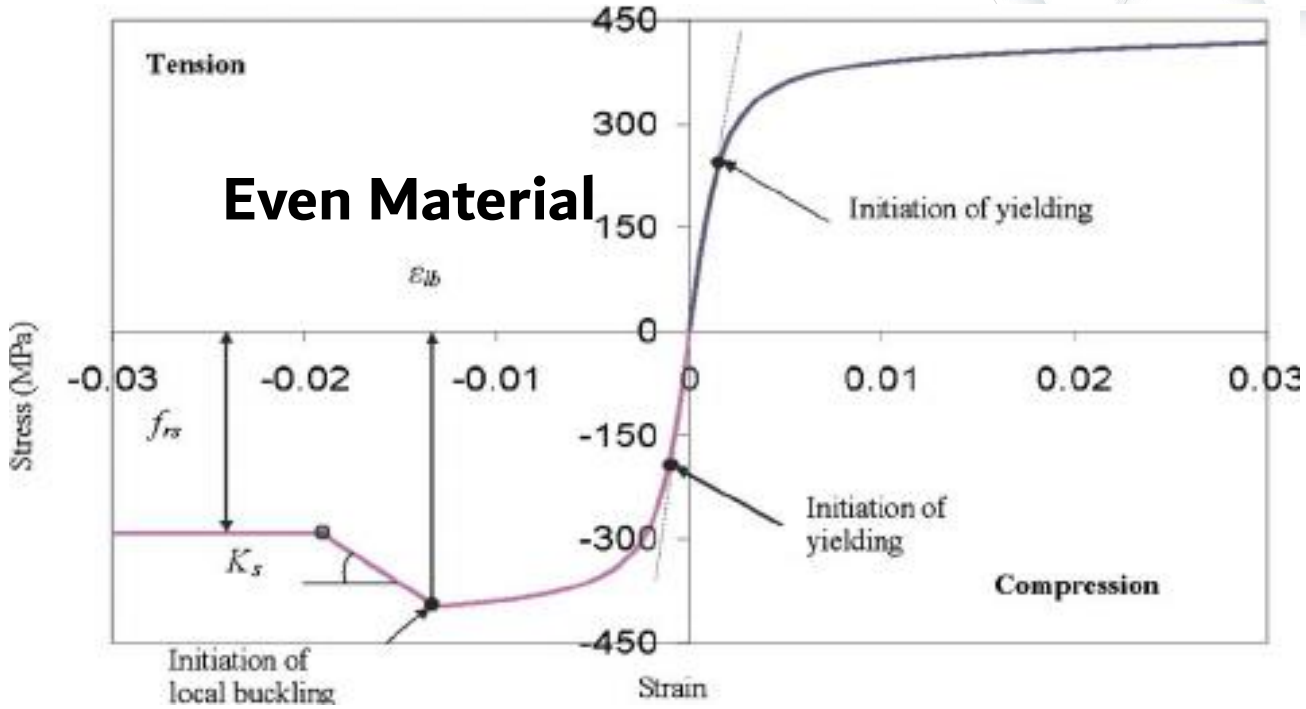
Spesimen Uji

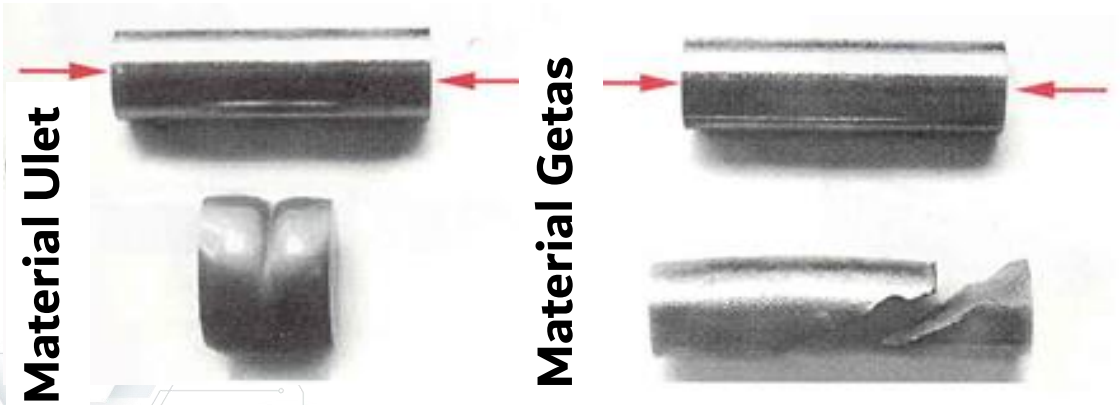


Sumber:
http://info.admet.com/Portals/70514/images/ADMET%20ASTM%20D2412%20Pipe%20Compression%20Test%202.jpg
http://www.fhwa.dot.gov/publications/research/infrastructure/structures/06103/images/fig23.jpg

Uji Tekan





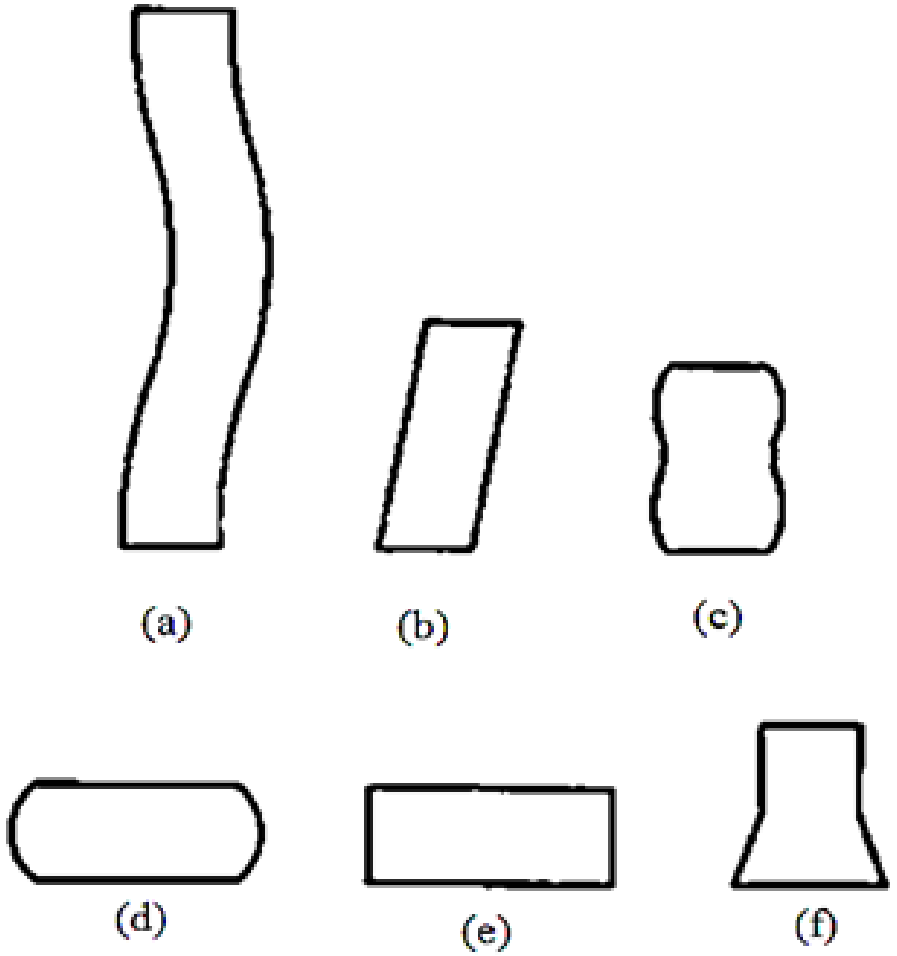


Sifat Mekanik

$$S_{yc} \quad S_{uc} \quad E_c$$

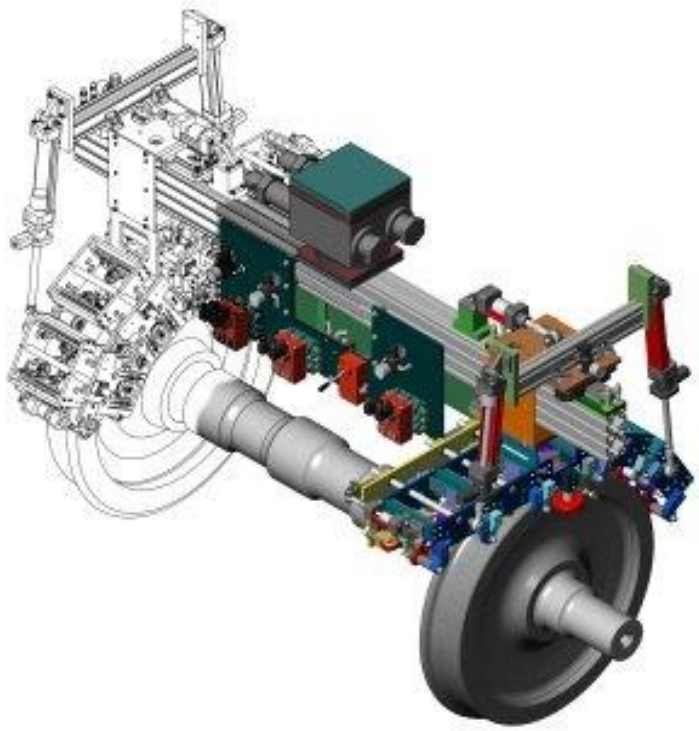
Sumber: https://bit.ly/36xIvzf

Mode Deformasi pada Uji Tekan



Gbr	L/D	Kemungkinan
a	> 5	*Buckling* / tertekuk
b	> 2.5	*Shearing* / Beban Geser
c	> 2.0	*Double barreling*, pengaruh gaya gesek besar
d	< 2.0	*Barreling*, pengaruh gaya gesek besar
e	< 2.0	Tertekan secara homogen, pengaruh gaya gesek bisa diabaikan
f		Ketidakstabilan karena adanya *softening*

Sumber:
https://sm-nitk.vlabs.ac.in/exp15/index.html



Modul 01
Review tentang Sifat Material

01.05. Uji Lentur

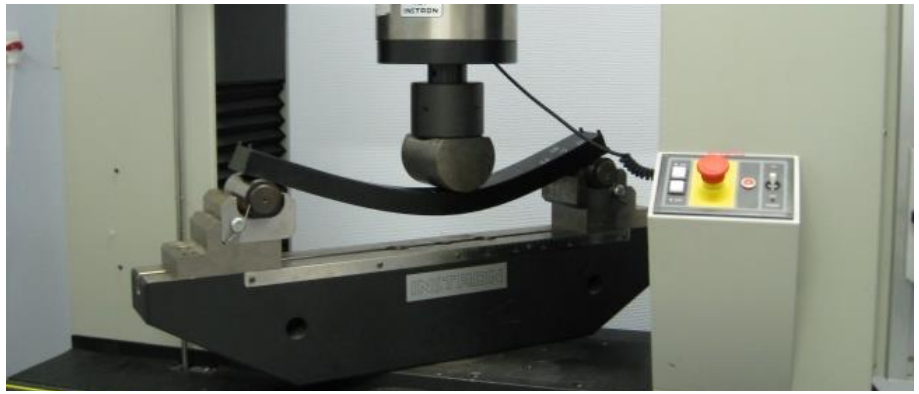
MS2210 - Elemen Mesin Dasar

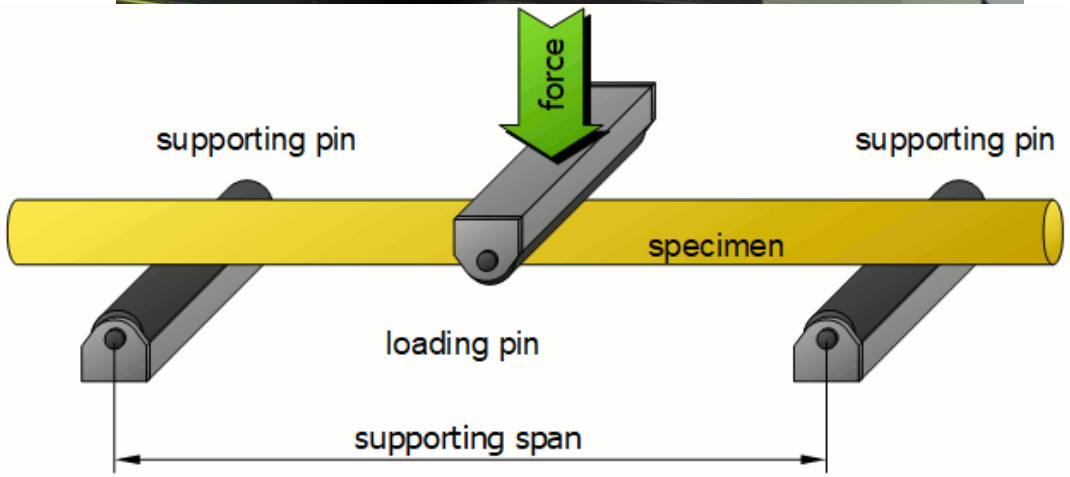
Teknik Mesin - FTMD ITB

Uji Lentur/Bending

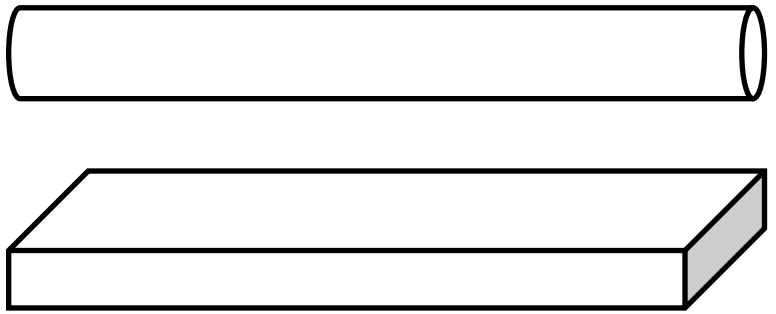
ASTM E290 - Standard Test Methods for **Bend Testing** of Material for Ductility

Mesin Uji



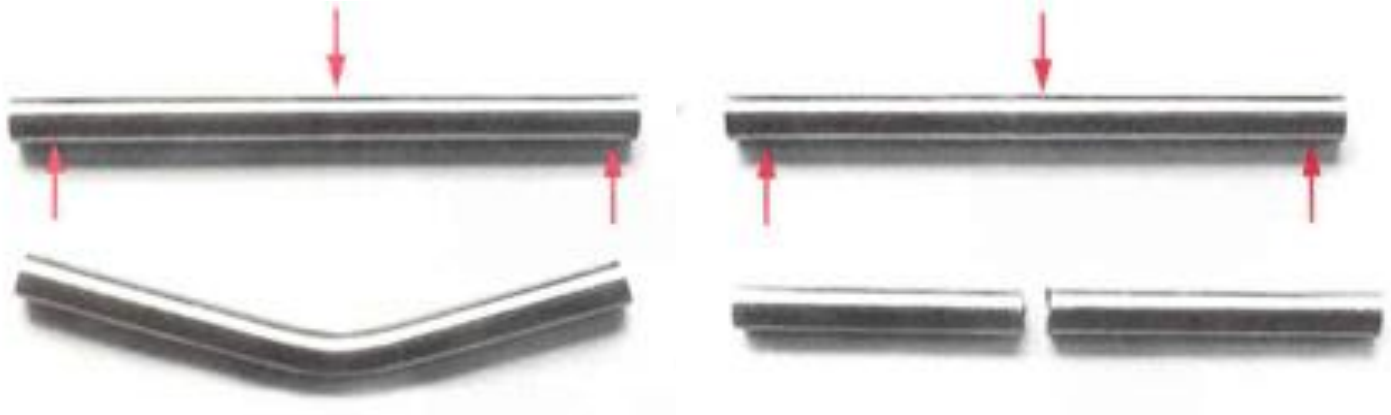


Spesimen Uji



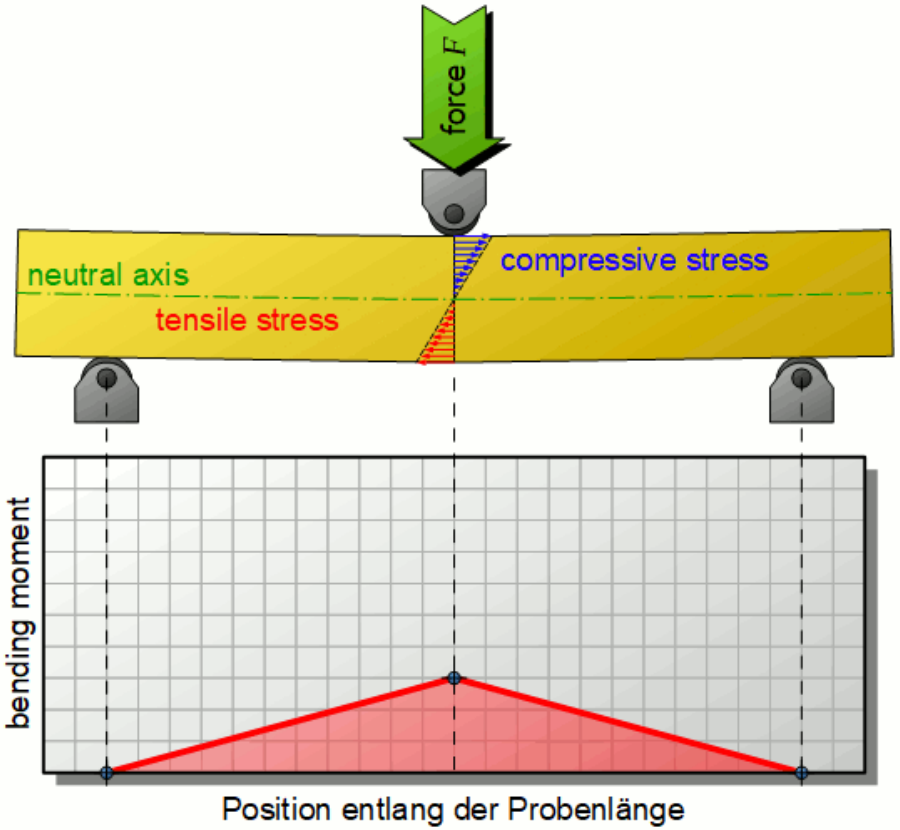
UJI BENDING

Sebuah batang tipis hanya ditopang di setiap ujungnya dan dibebani secara melintang di tengah panjangnya sampai gagal.



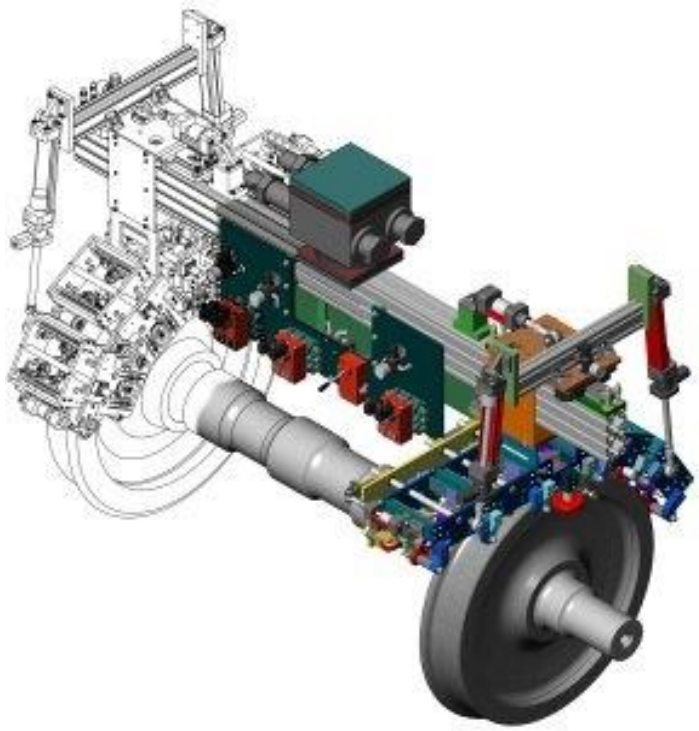
Material Ulet

Material Getas



Sifat Mekanik:

$$EI$$



Modul 01
Review tentang Sifat Material

01.06. Uji Puntir

MS2210 - Elemen Mesin Dasar

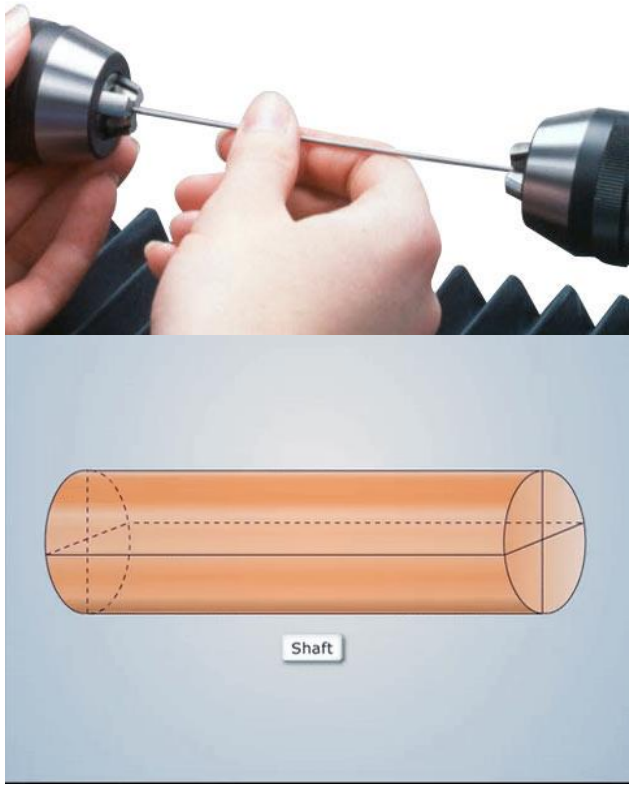
Teknik Mesin - FTMD ITB

Uji Puntir

ASTM A938 - Standard Test Method for **Torsion Testing** of Wire

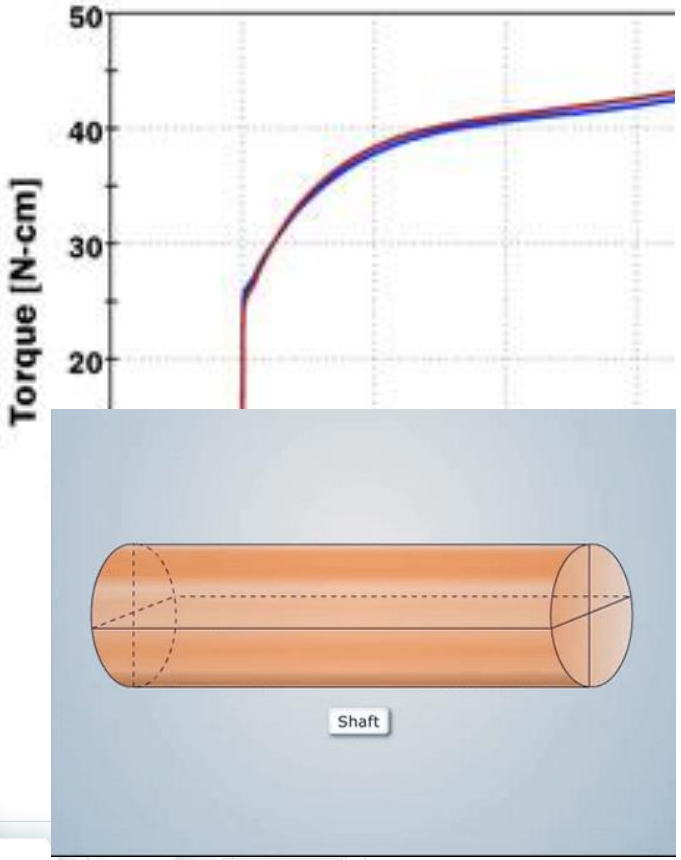
Mesin Uji

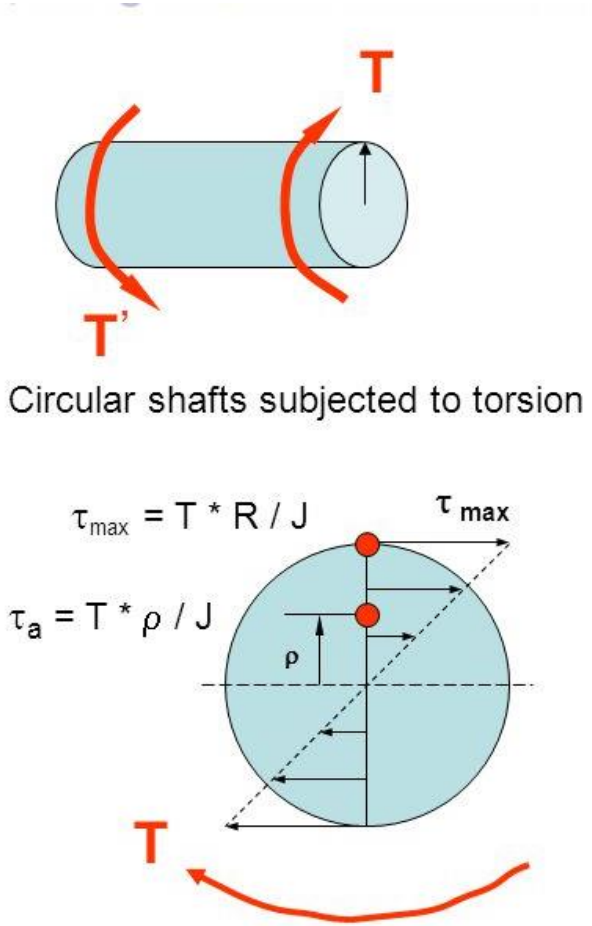
Specimen Uji

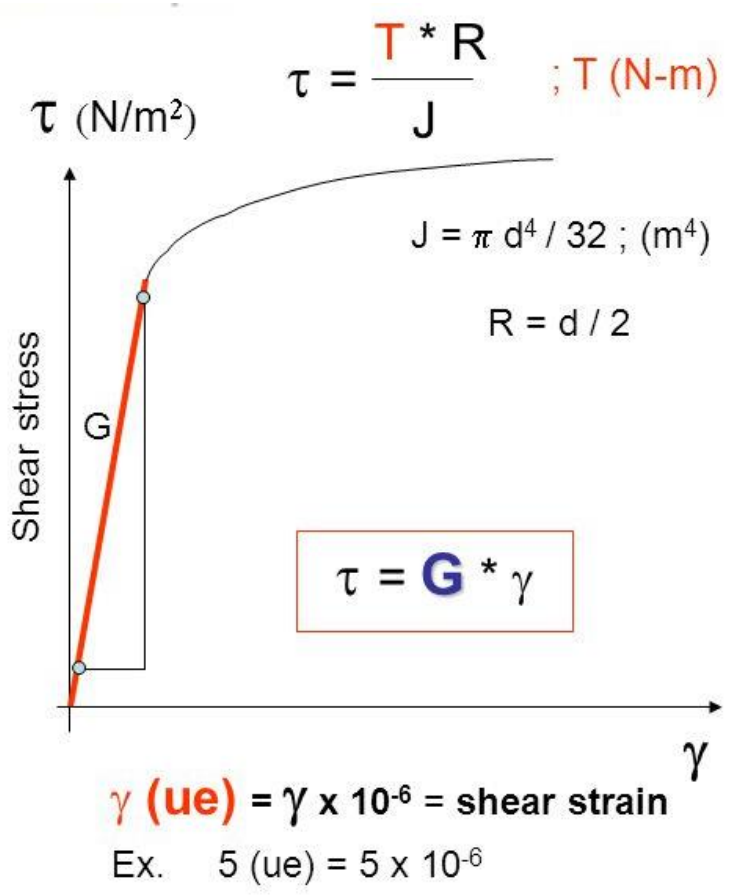


Sumber:
https://www.instron.cn/en/testing-solutions/by-test-type/torsion/astm-a938-iso-7800

Parameter dan Sifat Mekanik Uji Puntir







Uji Puntir

Sifat mekanik yang diperoleh dari uji torsi:

- *Modulus of Rigidity* (*Shear Modulus*): $\tau = \frac{Gr\theta}{l_0}$

- Kekuatan Geser Tertinggi (*Ultimate Shear Strength*):

$$S_{su} = \frac{Tr}{J}$$

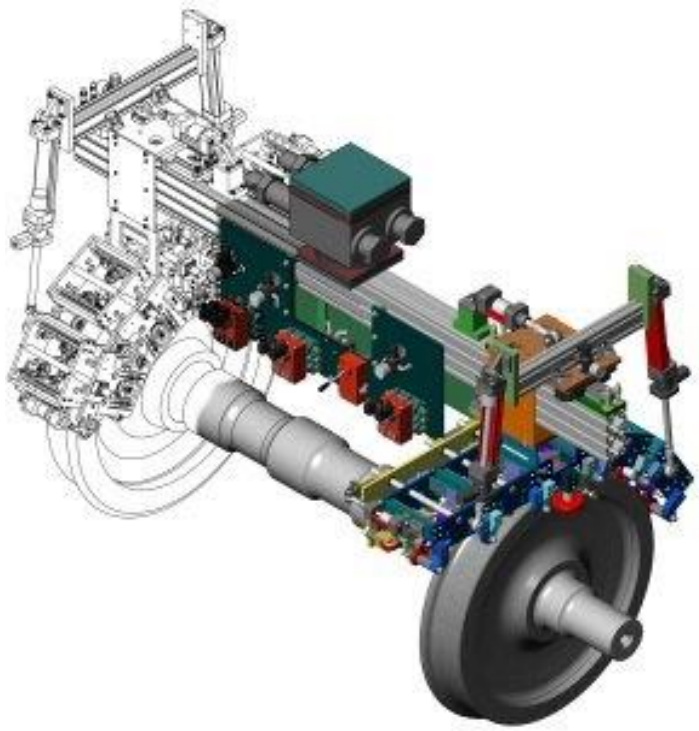
- Hubungan E, G dan υ:

$$G = \frac{E}{2(1+\upsilon)}$$

Jika data tidak ada, maka nilainya dapat didekati dg:

- Baja : $S_{su} \cong 0{,}80 S_{ut}$
- Material Ulet Lainnya : $S_{su} \cong 0{,}75 S_{ut}$

- Hubungan antara Shear Yield Strength dg Yield Strength:
  - Energi Distorsi : $S_{sy} \cong 0{,}57 S_y$
  - Tegangan Geser Maksimum : $S_{sy} \cong 0{,}50 S_y$



Modul 01
Review tentang Sifat Material

01.07. Uji Lelah (*Fatigue Test*)

MS2210 - Elemen Mesin Dasar

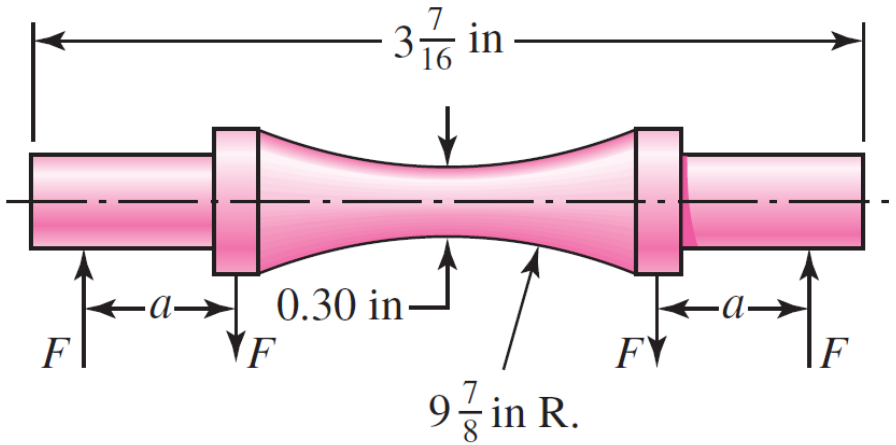
Teknik Mesin - FTMD ITB

Uji Lelah (*Fatigue Test*)

ISO 1143:2010 - Metallic materials — Rotating bar bending fatigue testing

Mesin Uji

Specimen Uji



Sumber:
http://www.iitg.ac.in/mech/images/labs/sml/10.JPG
https://www.imrtest.com/mechanical-testing

Fatigue and Endurance Strength

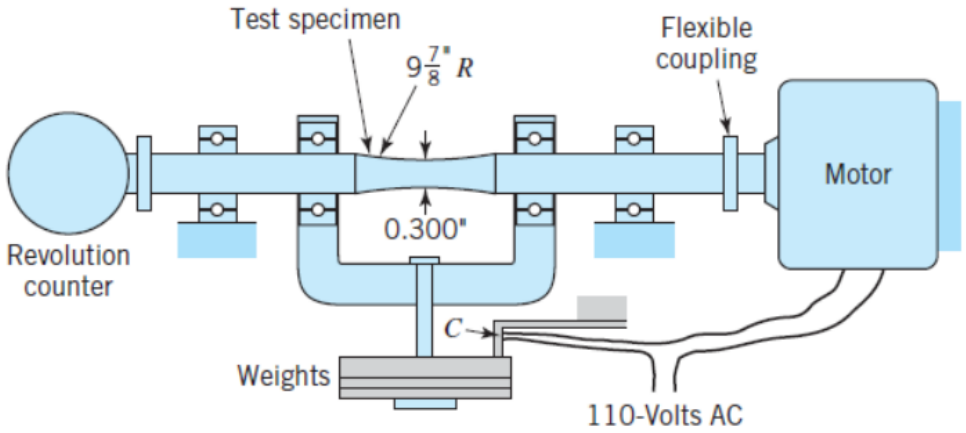
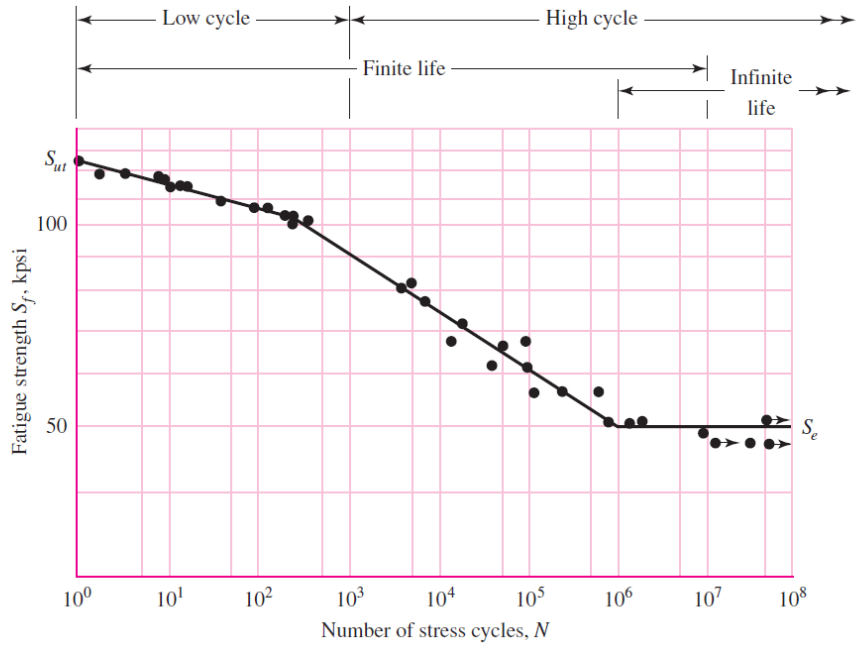


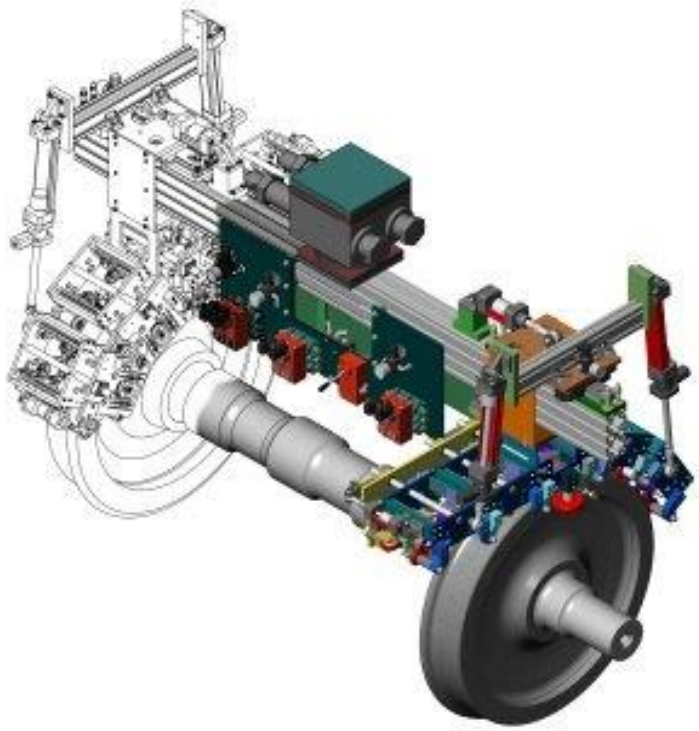
Figure 6–10

An *S-N* diagram plotted from the results of completely reversed axial fatigue tests. Material: UNS G41300 steel, normalized; $S_{ut} = 116$ kpsi; maximum $S_{ut} = 125$ kpsi. *(Data from NACA Tech. Note 3866, December 1966.)*



Benda uji diberi beban lentur sambil diputar (n = 1725 rpm) oleh motor, pengujian dilakukankan pada tingkat tegangan tertentu ***S*** sampai spesimen patah dan jumlah siklus ***N*** kemudian dicatat.

Kekuatan Lelah/ *Fatigue Strength* S_f dari satu siklus sama dengan kekuatan statis S_{ut}, dan nilainya terus menurun sampai mencapai nilai *endurance limit* pada sekitar 10^6 siklus.

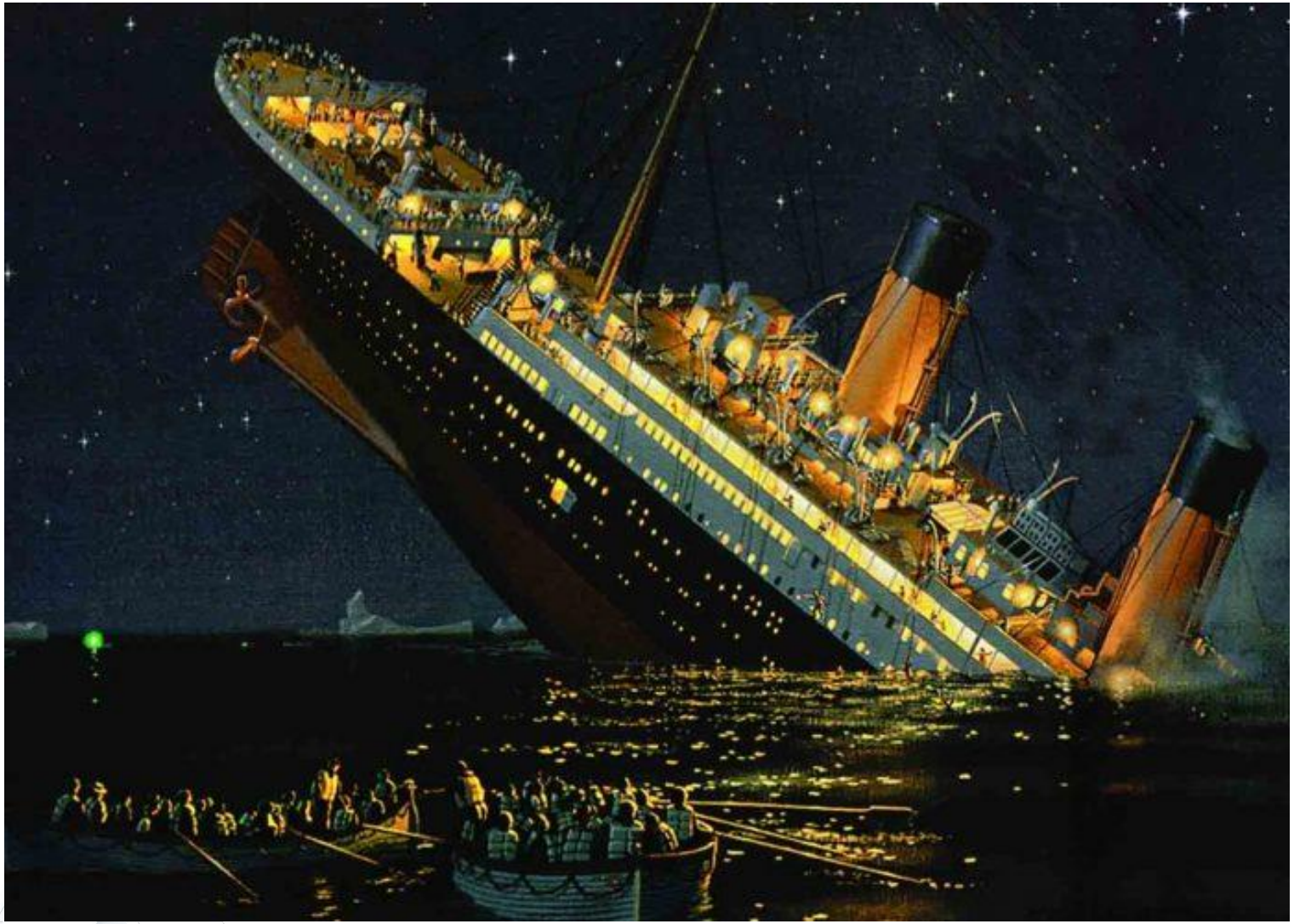


Modul 01
Review tentang Sifat Material

01.08. Uji Impak

MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

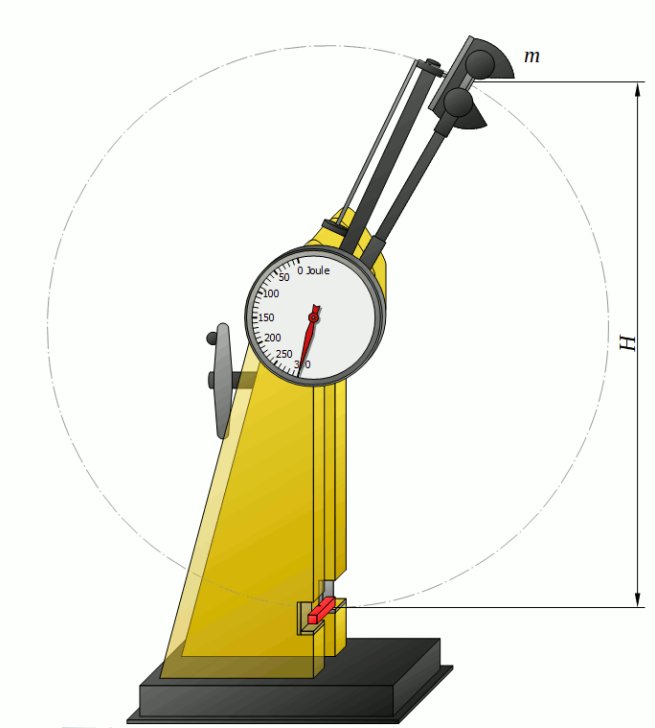


Material ulet (*ductile*), pada temperature rendah bisa berubah sifat menjadi getas (*brittle*).

Uji Impak Charpy

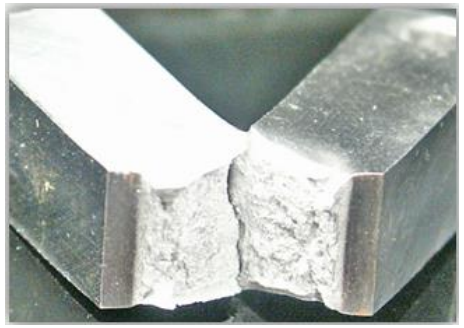
ASTM E23 - Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

Mesin Uji



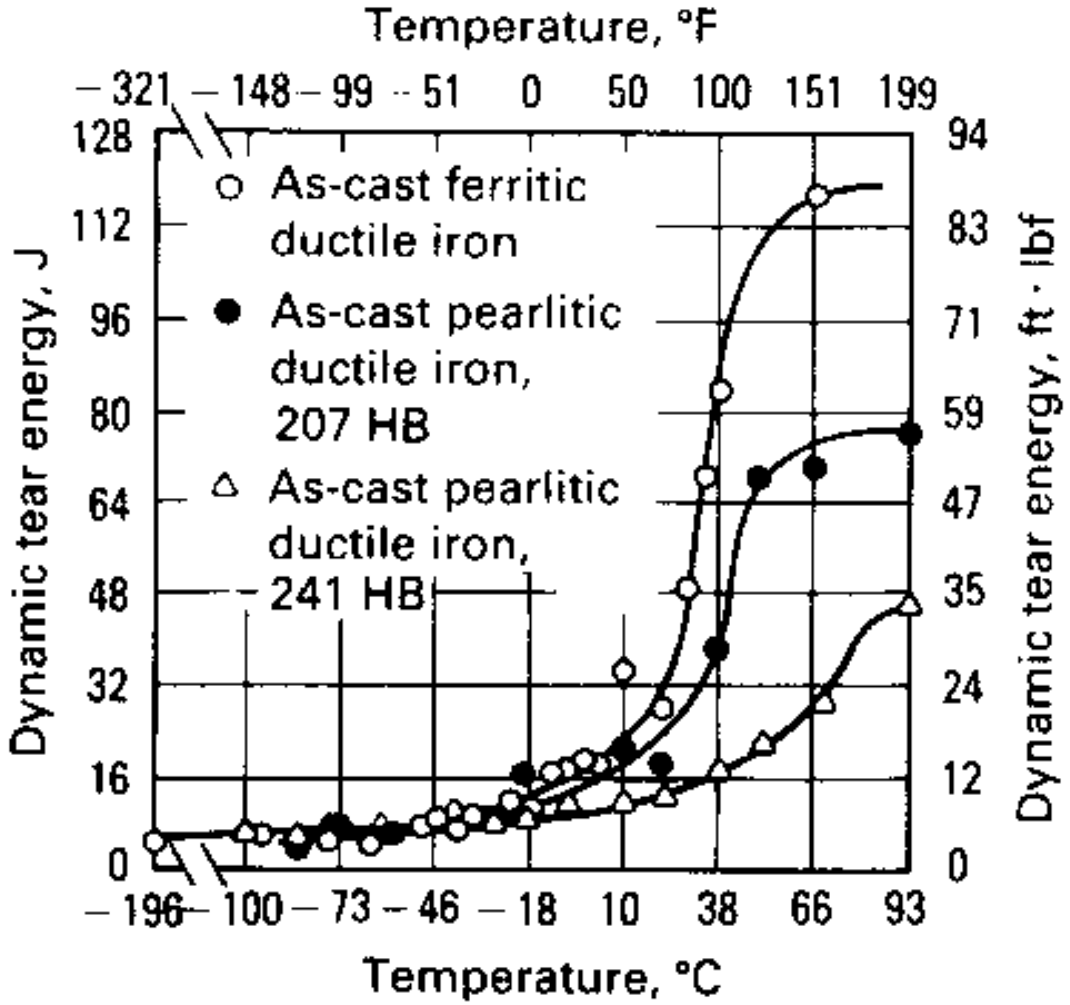
$$t < \frac{1}{3}\omega_n$$

Specimen Uji



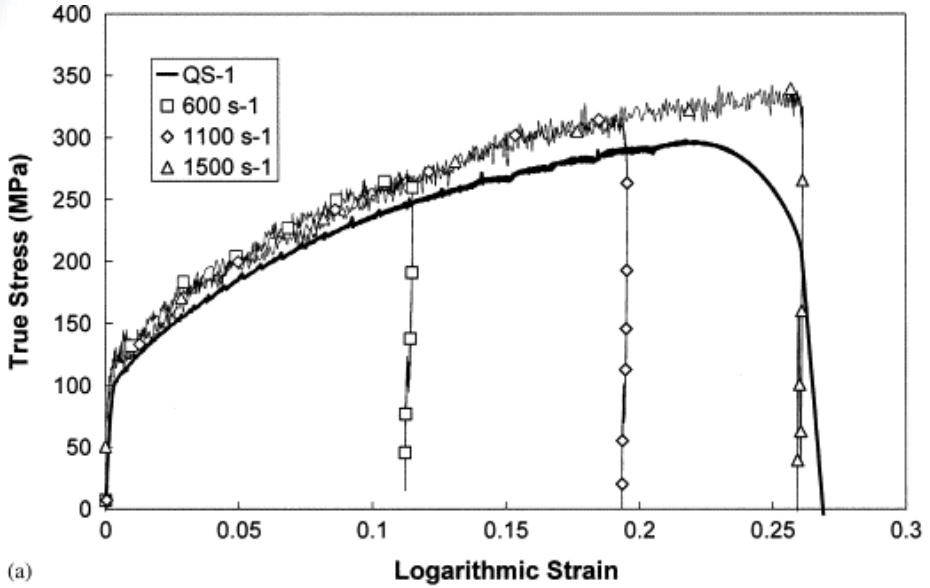
Sumber:
https://www.tec-science.com/material-science/material-testing/charpy-impact-test/

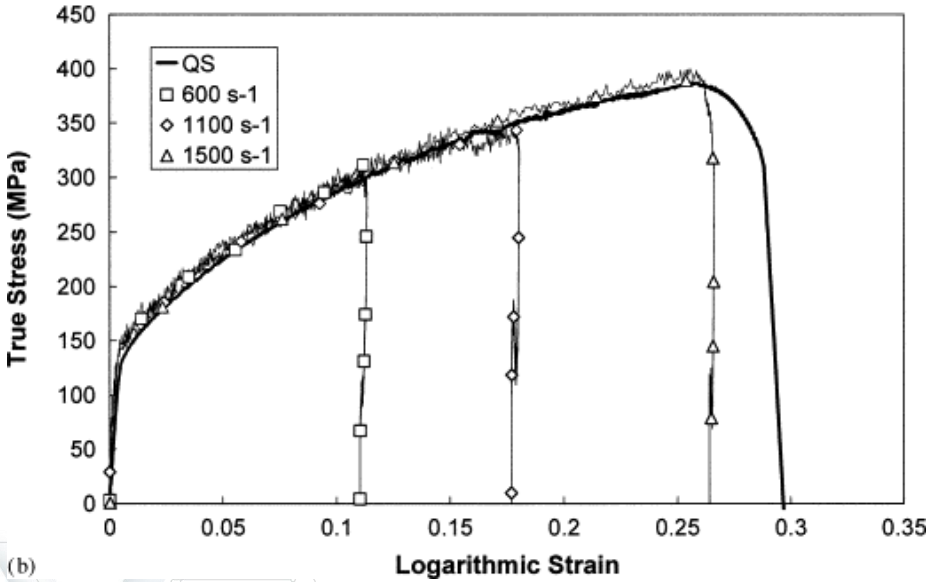
Hasil Uji Charpy



Sumber:
http://www.ductile.org/didata/Section3/Figures/fig3_50.gif

- Ketangguhan/
  Fracture Toughness:
  Energi yang diserap pada satuan luas sebelum material mengalami retak (J/m^2)





Beberapa material memiliki sifat yang berbeda ketika mendapatkan laju regangan yang tinggi

➔ *Strain Rate Sensitive Material*

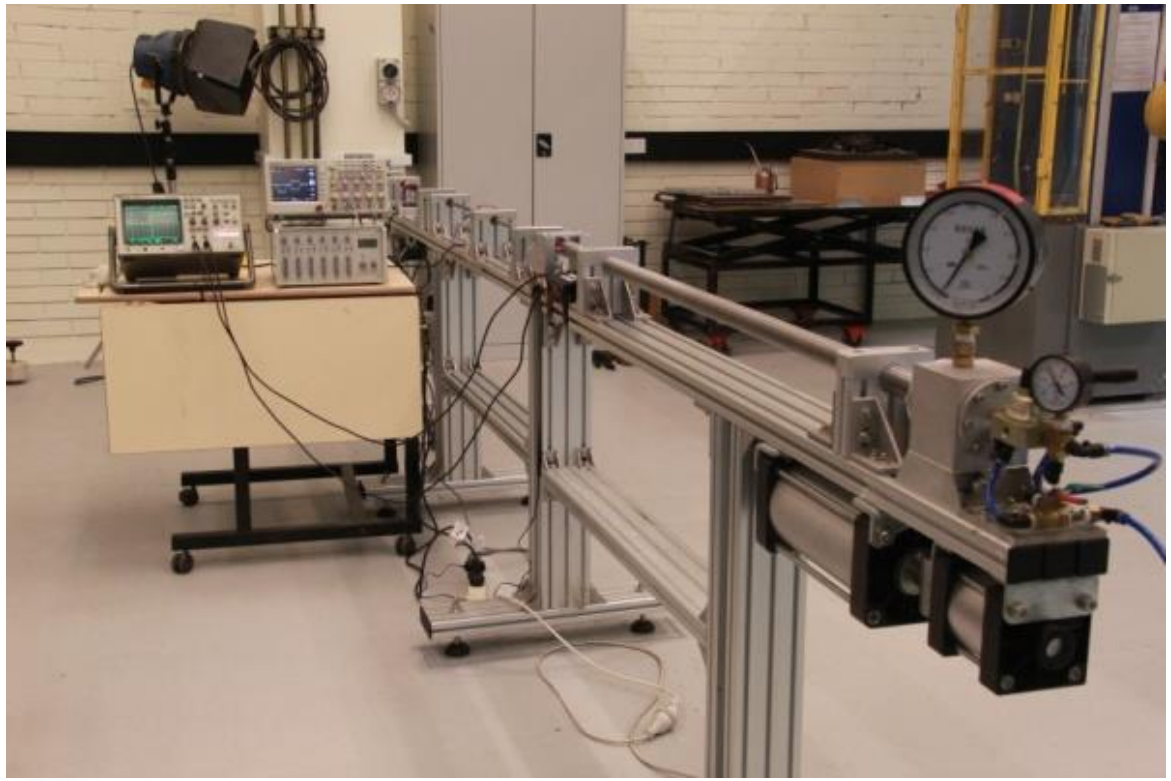
Namun, ada juga material memiliki sifat yang sama ketika mendapatkan laju regangan yang tinggi

➔ *Strain Rate Insensitive Material*

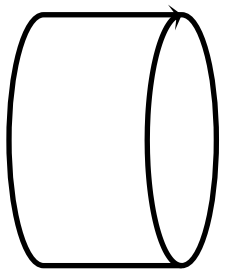
Sumber:
https://www.sciencedirect.com/science/article/abs/pii/S0734743X05000680

Split Hopkinson Pressure Bar (SHPB)

Mesin Uji

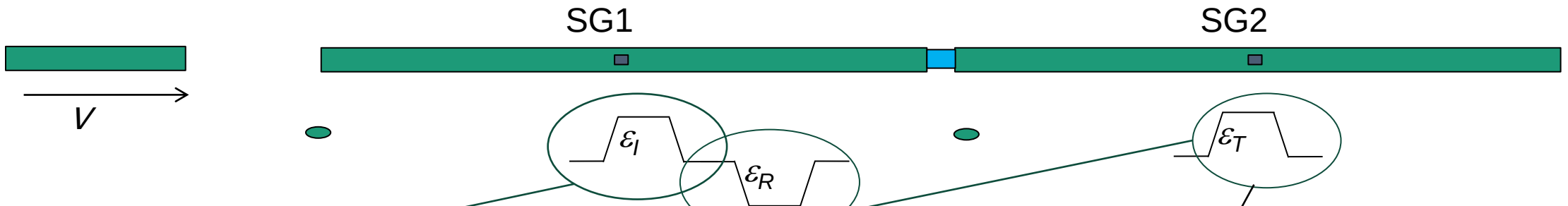


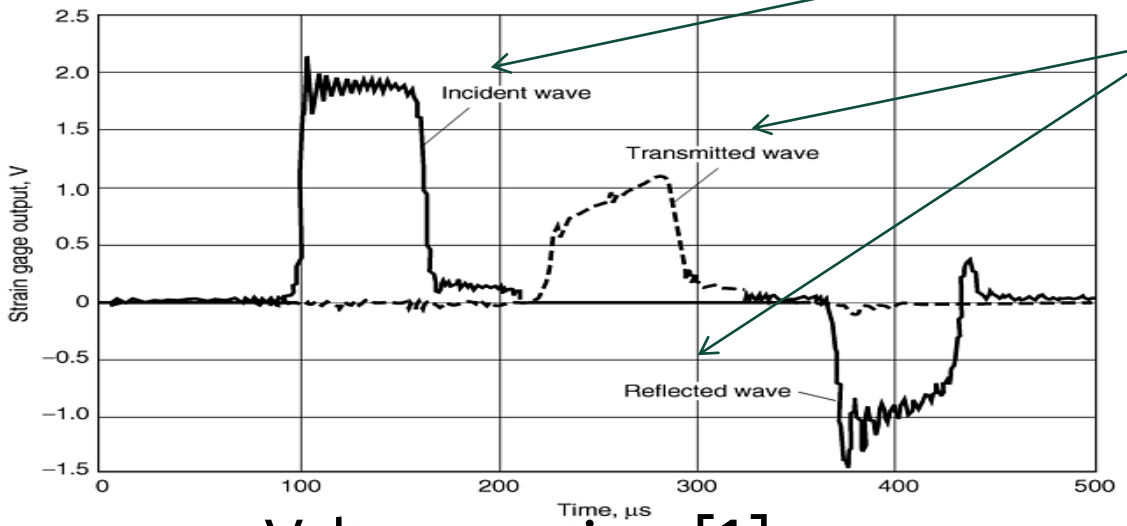
Specimen Uji



Disk silinder

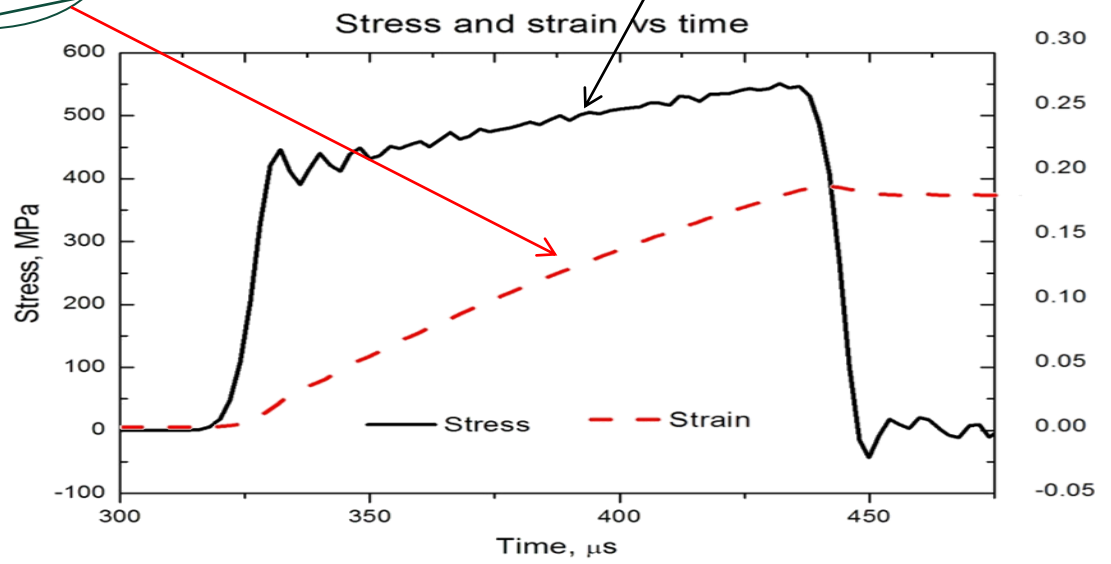
SHPB Testing: Data processing





Voltage vs. time [1]

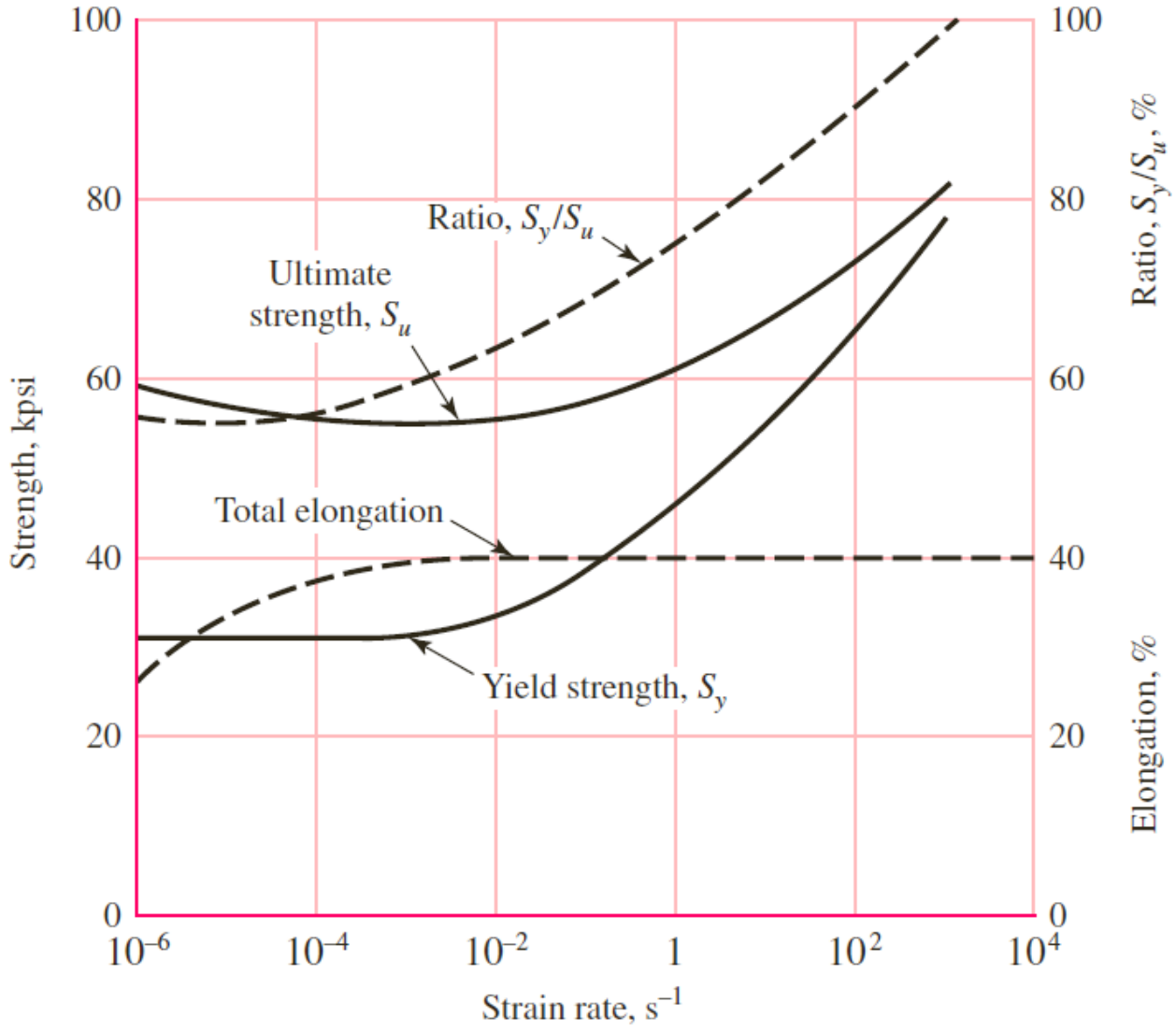
Data processing and correction

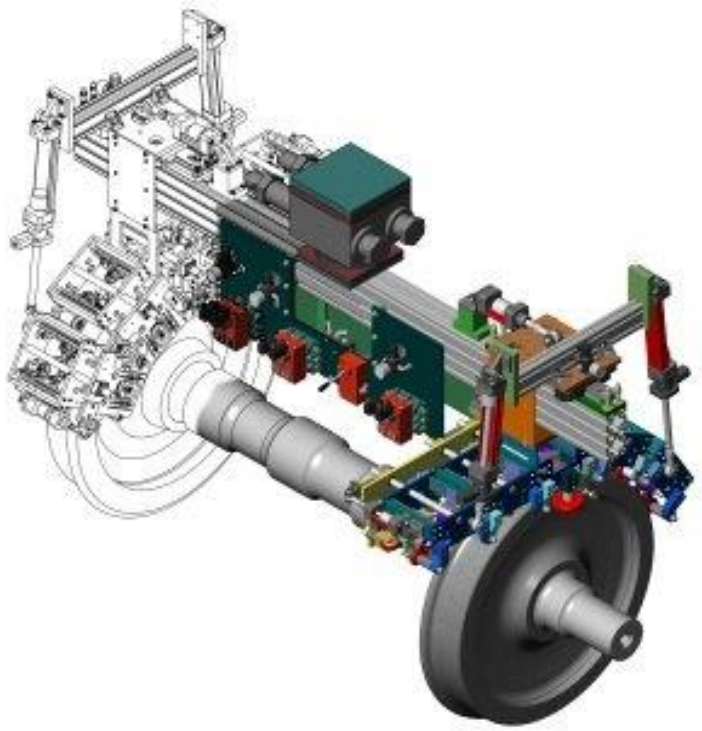


Stress vs. time
Strain vs. time

[1] G. Gray III, Classic Split-Hopkinson Pressure Bar Testing, in: H. Kuhn (Ed.) ASM Handbook, vol 8. Mechanical Testing and Evaluation, ASM International Materials Parks, Ohio, 2003.

Pengaruh laju regangan pada sifat material





Modul 01
Review tentang Sifat Material

01.10. Uji Keras

MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

Uji Keras

Mesin Uji

1) Macro Hardness Testers Loads > 1 kg
   - Rockwell
   - Brinell
   - Vickers
2) Micro Hardness Testers < 1 kg
   - Knoop diamond
   - Vickers diamond pyramid

Sumber:
http://www.finegrouptest.com/images/rockwell_hardness_tester.jpg

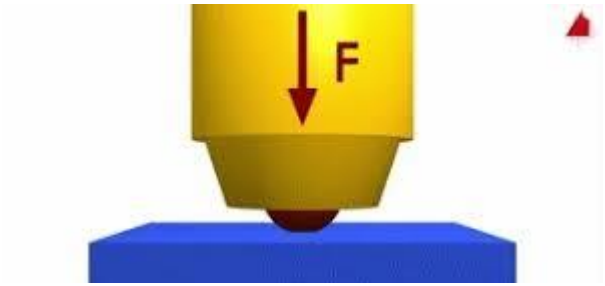
Spesimen Uji

Benda apa pun yang memiliki permukaan paralel

ASTM E10 - Standard Test Method for Brinell Hardness of Metallic Materials
ASTM E18 - Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E92 - Standard Test Method for Vickers Hardness of Metallic Materials
ASTM E103 - Standard Test Method for Rapid Indentation Hardness Testing of Metallic Materials
ASTM E110 - Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

Uji Keras

- Hambatan suatu material terhadap penetrasi dengan alat runcing disebut *kekerasan*



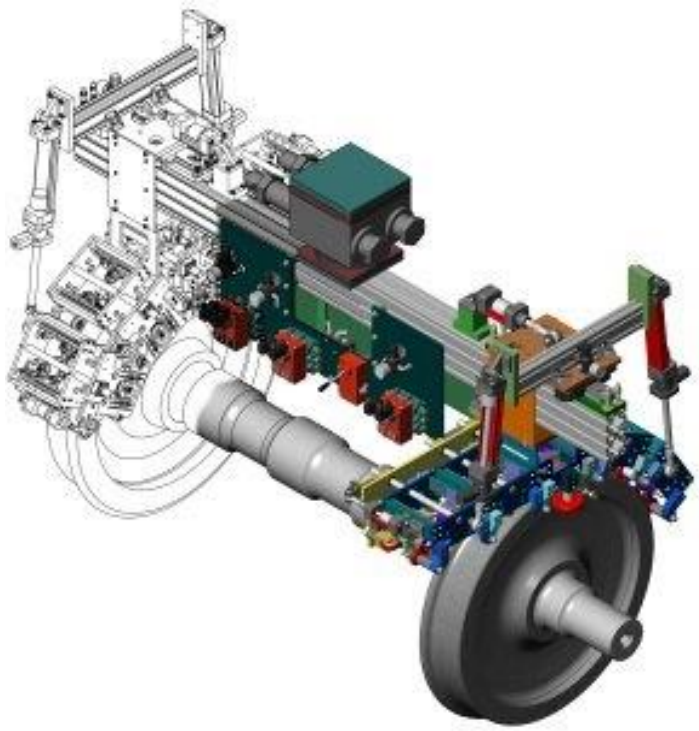
- Dua tes yang paling banyak digunakan:
  - *Kekerasan Rockwell: R_A , R_B, R_C,.... dll*
  - *Kekerasan Brinell*

Baja:

$$S_{ut} = \begin{cases} 0{,}5\ H_B & kpsi \\ 3{,}4 H_B & MPa \end{cases}$$

Besi cor:

$$S_{ut} = \begin{cases} 0{,}23\ H_B - 12{,}5 & kpsi \\ 1{,}58 H_B - 86 & MPa \end{cases}$$



Modul 01
Review tentang Sifat Material

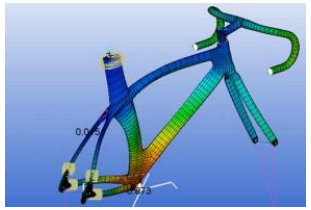
01.11. Pemilihan Material

MS2210 - Elemen Mesin Dasar

Teknik Mesin - FTMD ITB

Pemilihan Material

- Pemilihan material untuk bagian mesin atau bagian struktur adalah salah satu keputusan terpenting yang harus dibuat oleh perancang.



Tegangan - Regangan

Korosi

Beban Impak

Kekakuan

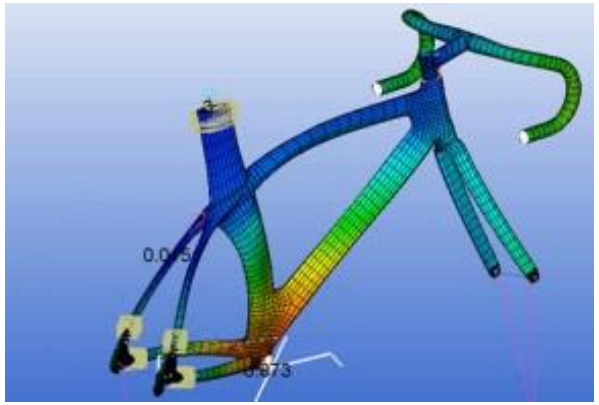
Konduktifitas Termal

Biaya

- MF Ashby telah mengembangkan metode sistematis dengan menggunakan pemilihan material secara grafik.

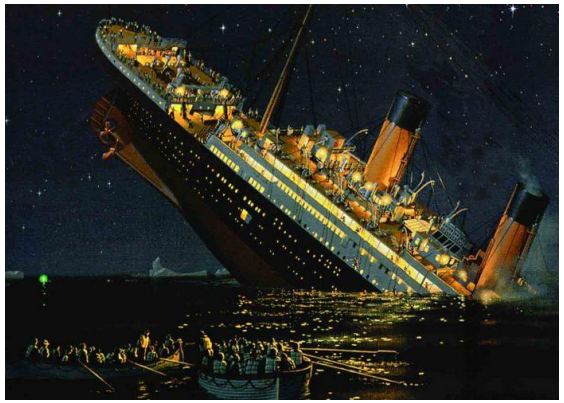
Desain Komponen –

Faktor yg dipertimbangkan

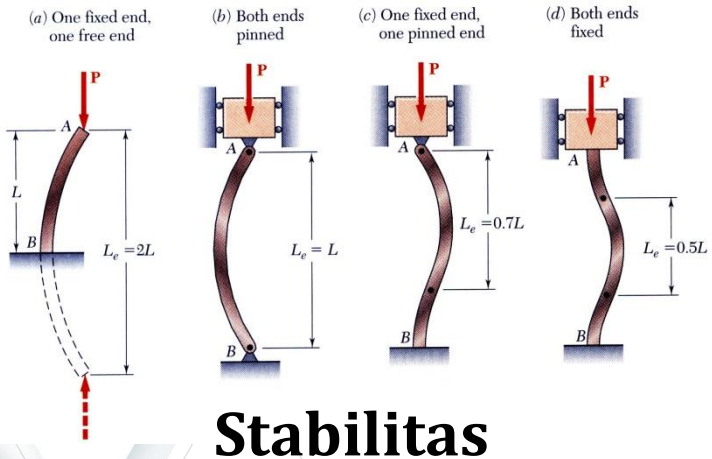


Tegangan - Regangan

Korosi



Beban Impak



Stabilitas

Konduktifitas Termal

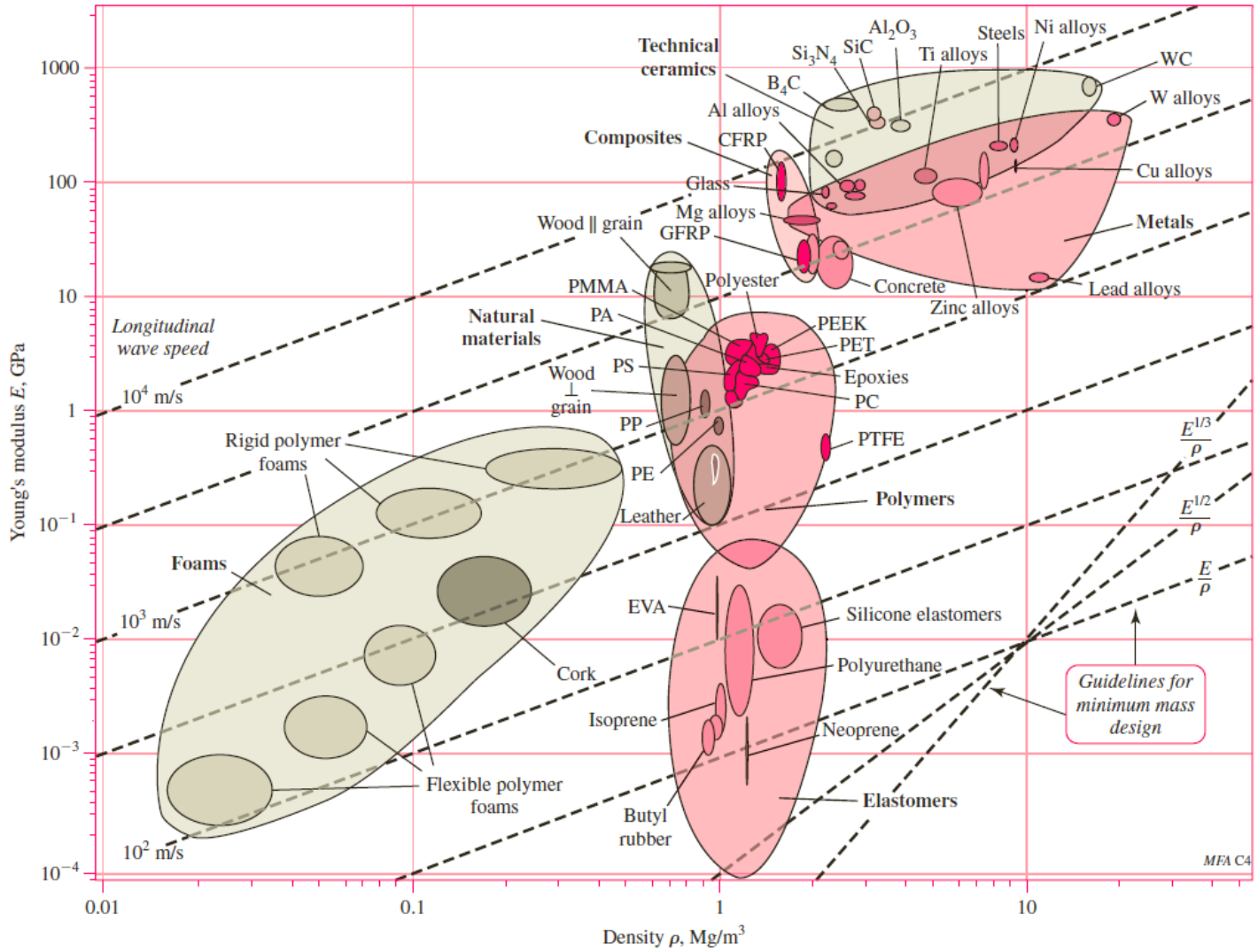
Kekakuan

Klasifikasi Material

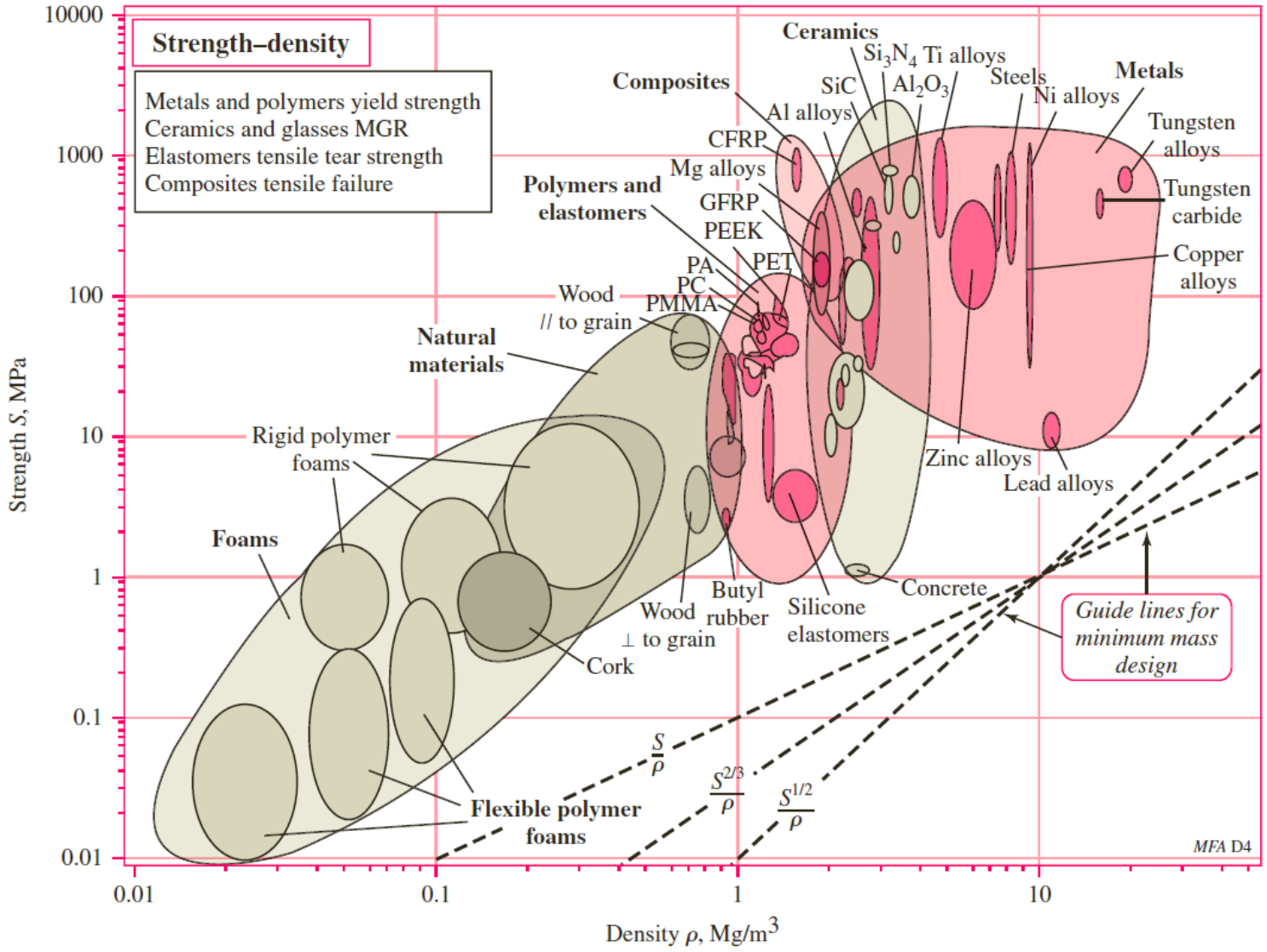
Family	Classes	Short Name
Metals (the metals and alloys of engineering)	Aluminum alloys	Al alloys
	Copper alloys	Cu alloys
	Lead alloys	Lead alloys
	Magnesium alloys	Mg alloys
	Nickel alloys	Ni alloys
	Carbon steels	Steels
	Stainless steels	Stainless steels
	Tin alloys	Tin alloys
	Titanium alloys	Ti alloys
	Tungsten alloys	W alloys
	Lead alloys	Pb alloys
	Zinc alloys	Zn alloys
Elastomers (engineering rubbers, natural and synthetic)	Butyl rubber	Butyl rubber
	EVA	EVA
	Isoprene	Isoprene
	Natural rubber	Natural rubber
	Polychloroprene (Neoprene)	Neoprene
	Polyurethane	PU
	Silicon elastomers	Silicones
Hybrids	Carbon-fiber reinforced polymers	CFRP
Composites	Glass-fiber reinforced polymers	GFRP
	SiC reinforced aluminum	Al-SiC
Foams	Flexible polymer foams	Flexible foams
	Rigid polymer foams	Rigid foams
Natural materials	Cork	Cork
	Bamboo	Bamboo
	Wood	Wood

Family	Classes	Short Name
Ceramics	Alumina	Al_2O_3
Technical ceramics (fine ceramics capable of load-bearing application)	Aluminum nitride	AlN
	Boron carbide	B_4C
	Silicon carbide	SiC
	Silicon nitride	Si_3N_4
	Tungsten carbide	WC
Nontechnical ceramics (porous ceramics of construction)	Brick	Brick
	Concrete	Concrete
	Stone	Stone
Glasses	Soda-lime glass	Soda-lime glass
	Borosilicate glass	Borosilicate glass
	Silica glass	Silica glass
	Glass ceramic	Glass ceramic
Polymers (the thermoplastics and thermosets of engineering)	Acrylonitrile butadiene styrene	ABS
	Cellulose polymers	CA
	Ionomers	Ionomers
	Epoxies	Epoxy
	Phenolics	Phenolics
	Polyamides (nylons)	PA
	Polycarbonate	PC
	Polyesters	Polyester
	Polyetheretherkeytone	PEEK
	Polyethylene	PE
	Polyethylene terephalate	PET or PETE
	Polymethylmethacrylate	PMMA
	Polyoxymethylene(Acetal)	POM
	Polypropylene	PP
	Polystyrene	PS
	Polytetrafluorethylene	PTFE
	Polyvinylchloride	PVC

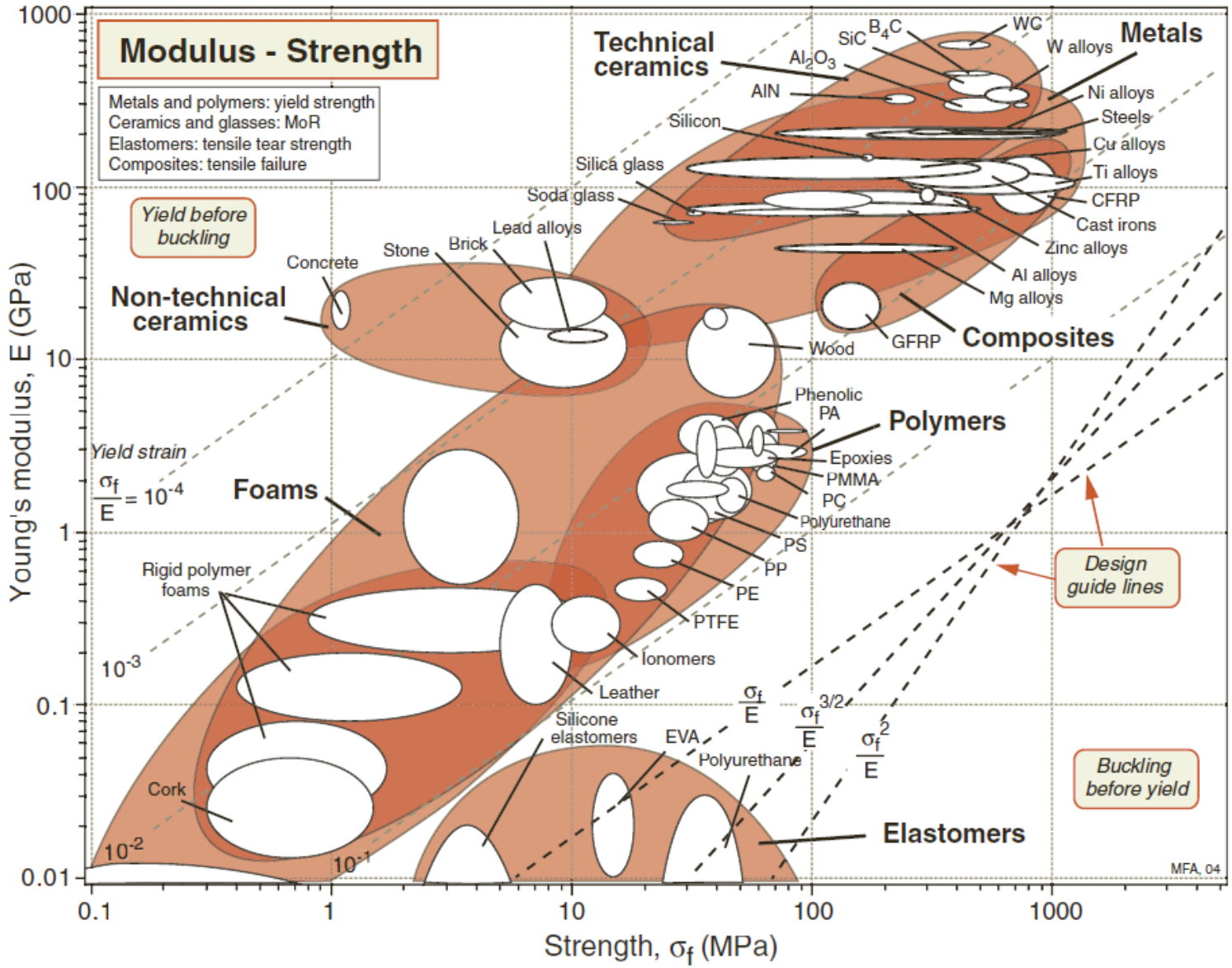
Modulus Elastisitas vs. Rapat Masa



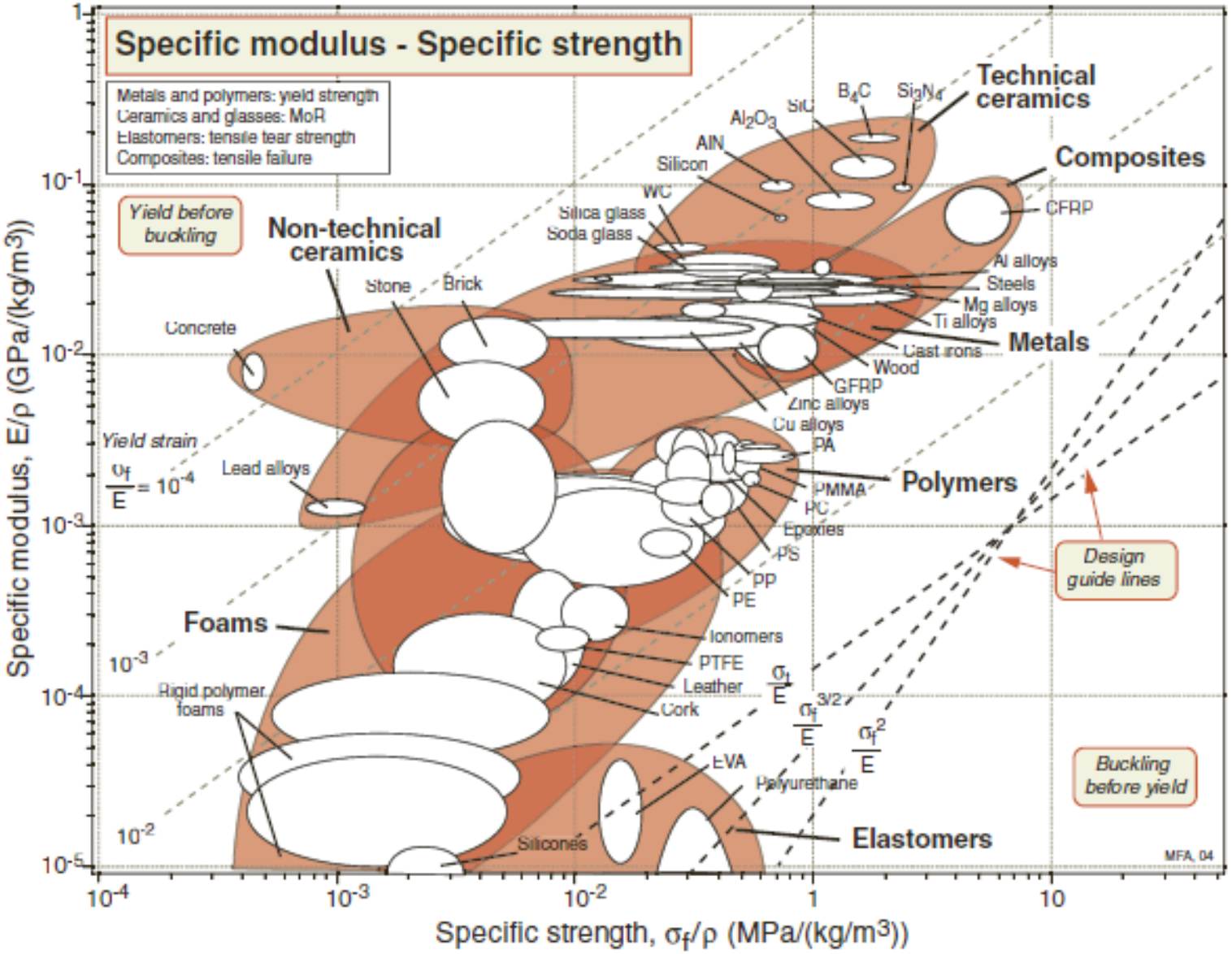
Kekuatan vs. Rapat Masa



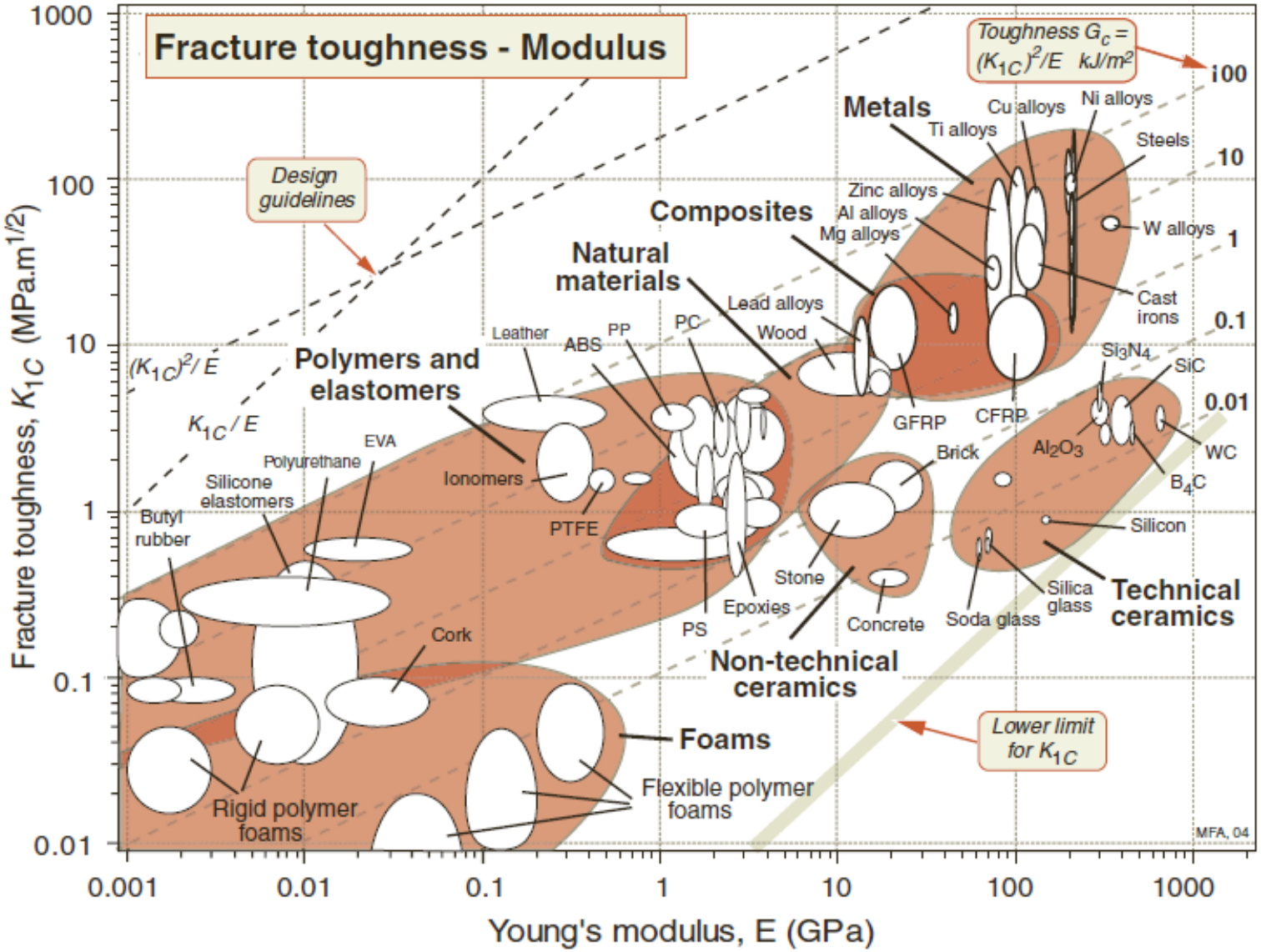
Modulus Elastisitas vs. Kekuatan



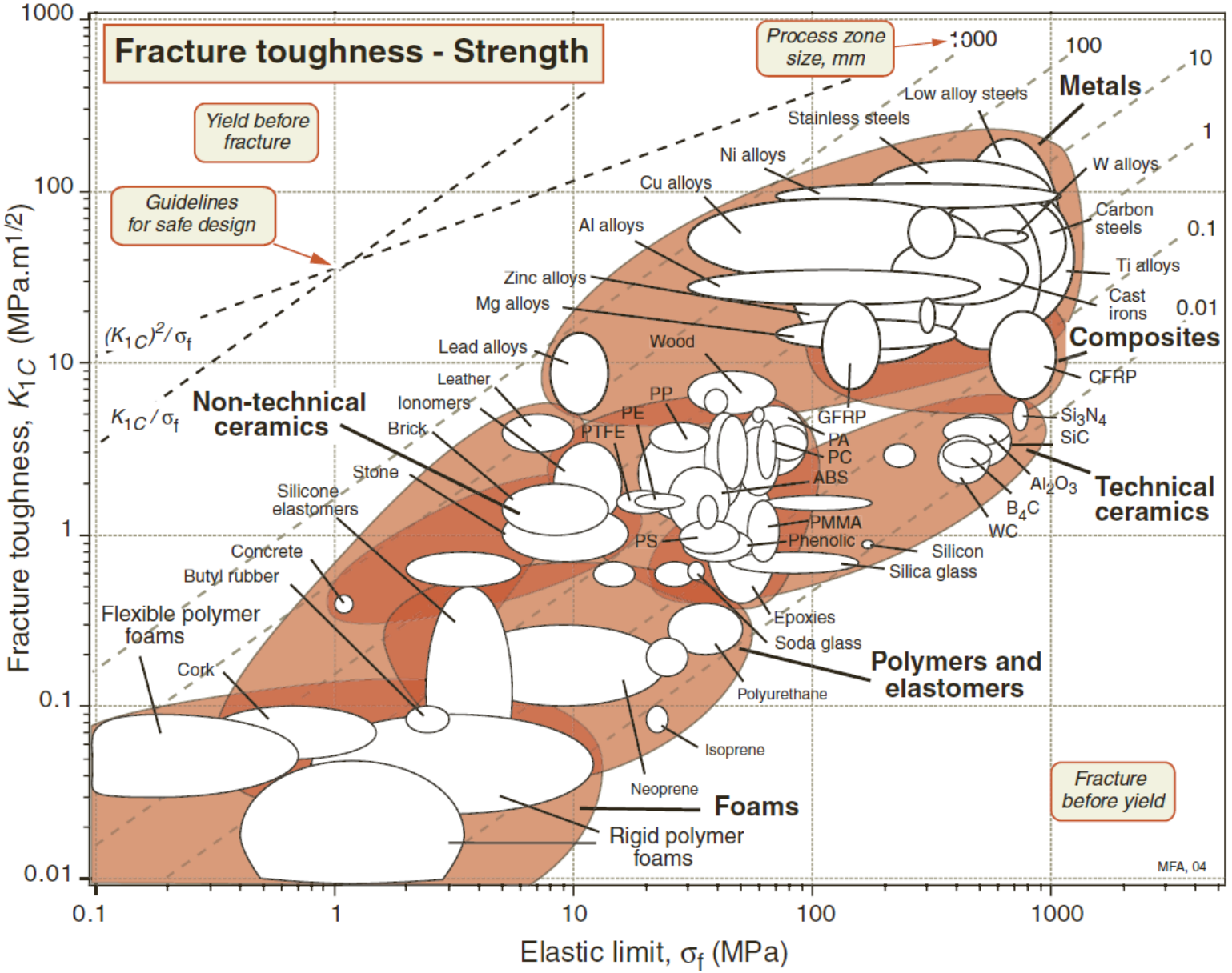
Modulus Elastisitas Spesifik vs. Kekuatan Spesifik



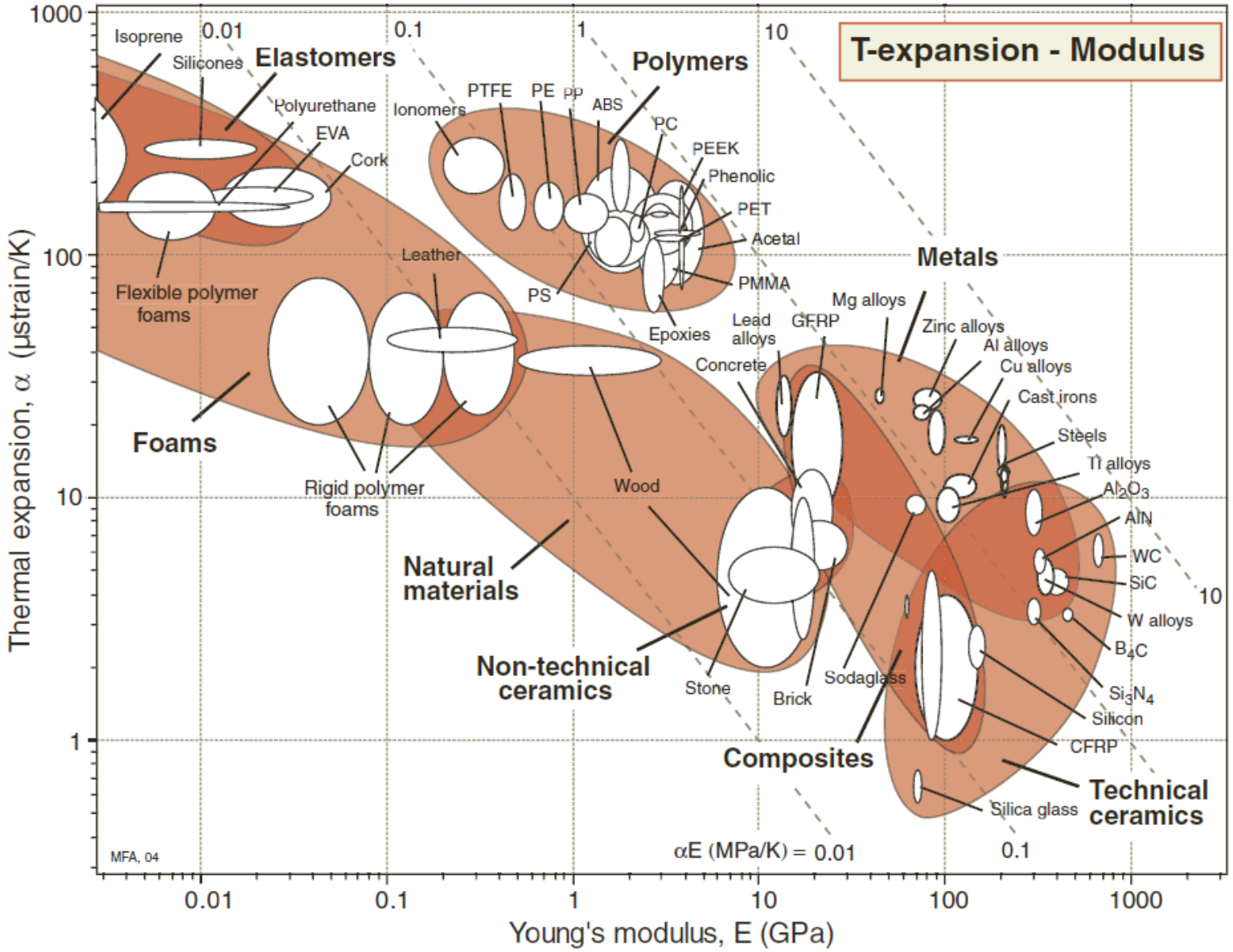
Ketangguhan vs. Modulus Elastisitas



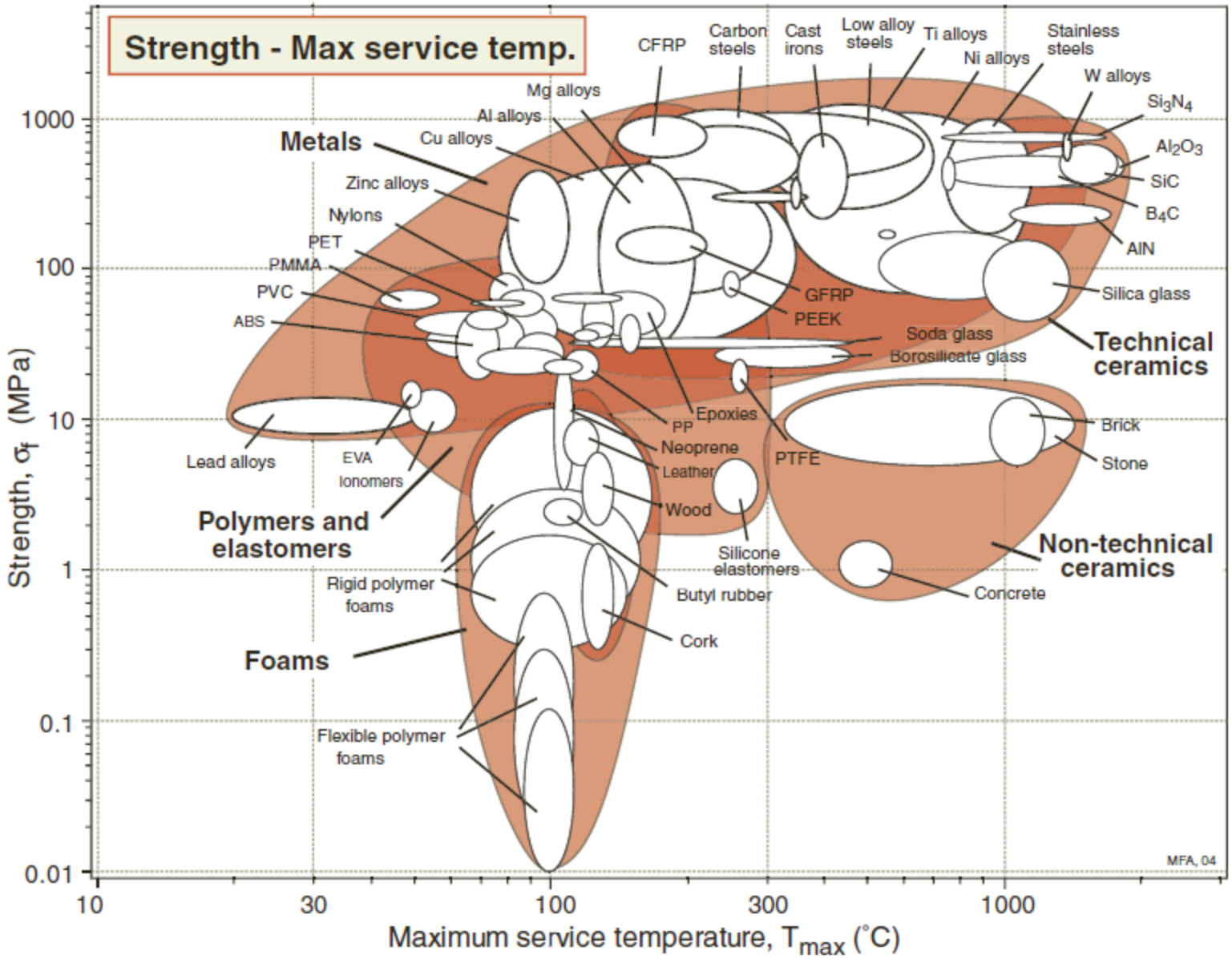
Ketangguhan vs. Batas Elastisitas



Ekspansi Termal vs. Modulus Elastisitas



Kekuatan vs. Temperatur Operasi Maksimum



Terima Kasih

Tim Pengajar
Fakultas Teknik Mesin dan Dirgantara
Institut Teknologi Bandung

Modul 01 Review tentang Sifat Material