Chapter 9

THE MATERIALS SELECTION PROCESS

Chapter 9: Goal and objectives

The overall goal of this chapter is to illustrate how systematic selection procedures can be used to select optimum materials and processes for a given component.

The main objectives are to illustrate how to:

1. Analyze material performance requirements for a given application.
2. Create alternative solutions, screen them, and then rank the viable candidates.
3. Use quantitative methods in materials selection.
4. Incorporate computer methods in the selection process.
5. Find reliable sources of material properties.

The nature of the selection process

Selecting the optimum combination of material and process cannot be performed at one certain stage in the history of a project, it should gradually evolve during the different stages of product development.

After identifying the function of the component, the following questions become important:

- What are the primary design and material requirements?
- What are the secondary requirements and are they necessary?

General steps in materials selection

1. Analysis of the performance requirements.
2. Development of alternative solutions to the problem.
3. Evaluation of the different solutions.
4. Decision on the optimum solution.

Fig. 9.1 Major stages of design and the related stages of materials selection I

Stages of Design		Stages of Materials Selection
Preliminary and Conceptual Design Translate marketing ideas into industrial design leading to broad description of the product: What is it? What does it do? How does it do it? How much should it be? Formulate product specifications, develop various concepts and select the optimum concept Decompose the product into subassemblies and identify the different parts of each subassembly. Specifying the main function of each part and identify their critical requirements.		**Analysis of material performance requirements** **Creating alternative material and process solutions for the optimum concept**
		Initial Screening Use the critical requirements of each part to define the performance requirements of the material. Start with all materials available and narrow down the choices on the basis of the rigid requirements.

Fig. 9.1 Major stages of design and the related stages of materials selection II

Stages of Design	Stages of Materials Selection
Configuration (Embodiment) Design Develop a qualitative sketch of each part giving only the order of magnitude of the main dimensions but showing the main features – walls, bosses, ribs, holes, grooves, etc	**Comparing Alternative Solutions** Use soft material requirements to further narrow the field of possible materials to a few optimum candidates.

Fig. 9.1 Major stages of design and the related stages of materials selection III

Stages of Design		Stages of Materials Selection
Detail (Parametric) Design Determine the dimensions and features of the parts based on a specific material and a manufacturing process taking into account the design limitations, the manufacturing process, weight concerns, space limitations, etc. The cost must now be considered in detail. Generation of an alternative detail design, which requires selecting a design based on alternative materials and evaluation against requirements.		**Selection of Optimum Solution** Use the optimum materials and matching manufacturing processes to make detail designs. Compare alternative combinations taking into account the elements of cost. Select optimum combination of design-material-manufacturing process

Analysis of material performance requirements

The material performance requirements can be divided into 5 broad categories:

- Functional requirements
- Processability requirements
- Cost
- Reliability requirements
- Resistance to service conditions

Creating alternative solutions

Having specified the material requirements, the rest of the selection process involves the search for the material that would best meet those requirements.

The starting point is the entire range of engineering materials.

At this stage, it is essential to open up channels in different directions. A steel may be the best material for one design concept while a plastic is best for a different concept, even though the two designs provide similar functions.

The importance of this phase is that it creates alternatives without much regard to their feasibility.

Initial screening of solutions I

Rigid materials and process requirements

Initial screening of materials can be achieved by first classifying their performance requirements into two main categories:

- Rigid, or go-no-go, requirements.
- Soft, or relative, requirements.

Materials that do not satisfy the rigid requirements are eliminated. For example, metals and alloys are eliminated when selecting materials for an electrical insulator.

Initial screening of solutions II

Cost per unit property method

In the case of tensile members, the cost of unit strength

$$[(C\rho)/S]$$

can be used for initial screening. Materials with lower cost per unit strength are preferable. If an upper limit is set for the quantity $(C\rho)/S$, then materials satisfying this condition can be identified and used as possible candidates for more detailed analysis in the next stage of selection.

- Table 9.1 gives some formulas for cost per unit property under different loading conditions

Initial screening of solutions III

Table 9.1 Formulas for estimating cost per unit property

Cross-section and loading condition	Cost per unit strength	Cost per unit stiffness
Solid cylinder in tension or compression	$C\rho/S$	$C\rho/E$
Solid cylinder in bending	$C\rho/S^{2/3}$	$C\rho/E^{1/2}$
Solid cylinder in torsion	$C\rho/S^{2/3}$	$C\rho/G^{1/2}$
Solid cylindrical bar as slender column	---	$C\rho/E^{1/2}$
Solid rectangle in bending	$C\rho/S^{1/2}$	$C\rho/E^{1/3}$
Thin-walled cylindrical pressure vessel	$C\rho/S$	---

Initial screening of solutions IV
Case study 9.1-Selecting a beam material for minimum cost I

A simply supported beam of rectangular cross section of length 1 meter, width 100 mm, and no restriction on the depth is subjected to a load of 20 kN in its middle.

The main design requirement is that the beam should not suffer plastic deformation as a result of load application.

Select the least expensive material for the beam from Table 9.2.

Initial screening of solutions IV
Case study 9.1-Selecting a beam material for minimum cost II

Table 9.2 Characteristics of candidate materials for the beam

Material	Working stress[a] MPa	ksi	Specific gravity	Relative cost[b]	Cost of unit unit strength
Steel AISI 1020, normalized	117	17	7.86	1	0.73
Steel AISI 4140, normalized	222	32	7.86	1.38	0.73
Aluminum 6061, T6 temper	93	13.5	2.7	6	1.69
Epoxy+70% glass fibers	70	10.2	2.11	9	2.26

a The working stress is computed from yield strength using a factor of safety of 3.

b The relative cost per unit weight is based on AISI 1020 steel as unity.Material and processing costs are included in the relative cost.

Initial screening of solutions IV
Case study 9.1-Selecting a beam material for minimum cost III

Solution:

- Based on Table 9.2 and the appropriate formula from Table 9.1, the cost of unit strength for the different materials is calculated and the results are given in the last column of Table 9.2.

- The results show that steels AISI 1020 and 4140 are equally suitable, while Al 6061 and epoxy - glass are more expensive.

Ashby's method for initial screening I

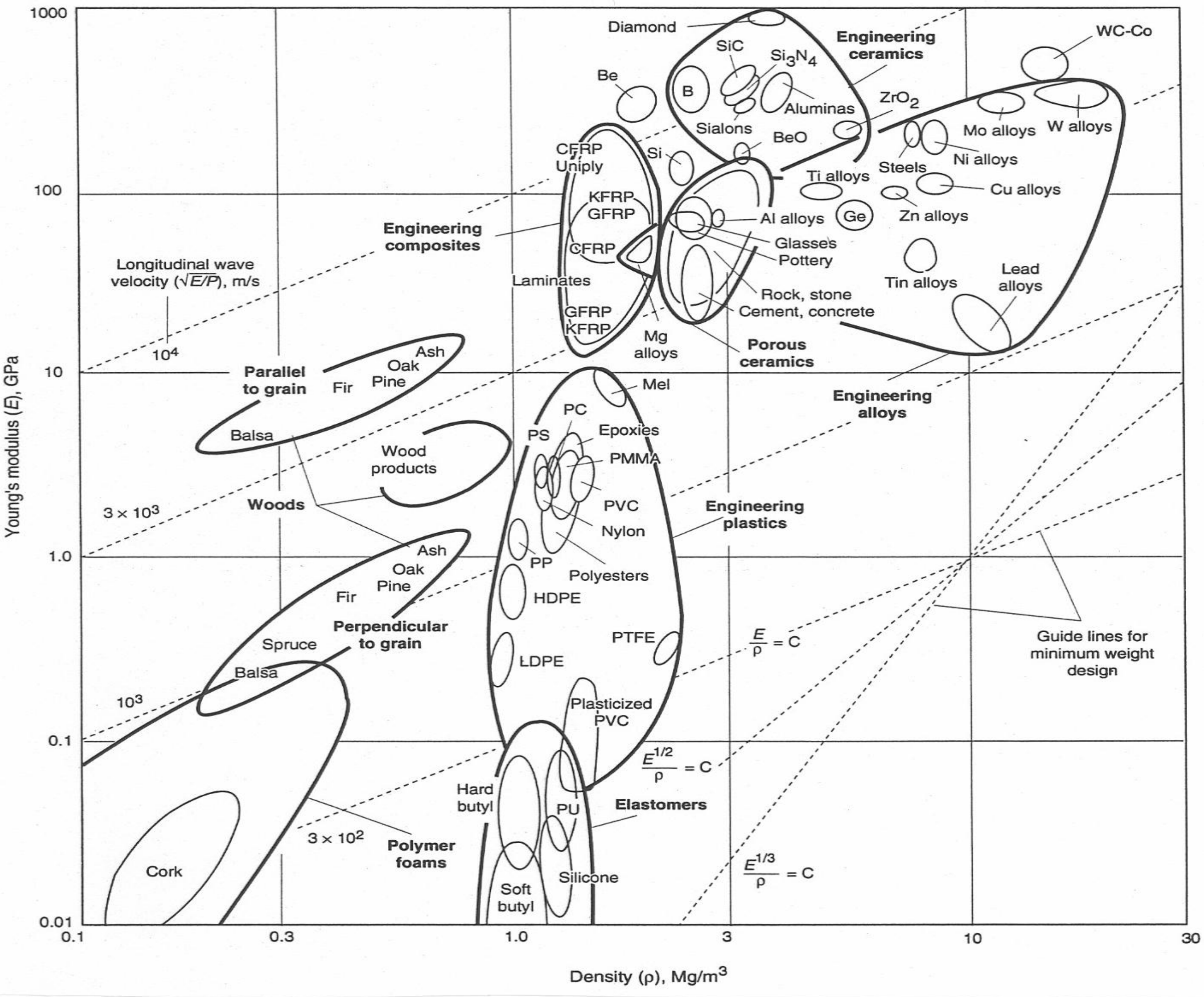


Fig.9.2(a)

Ashby’s method for initial screening II

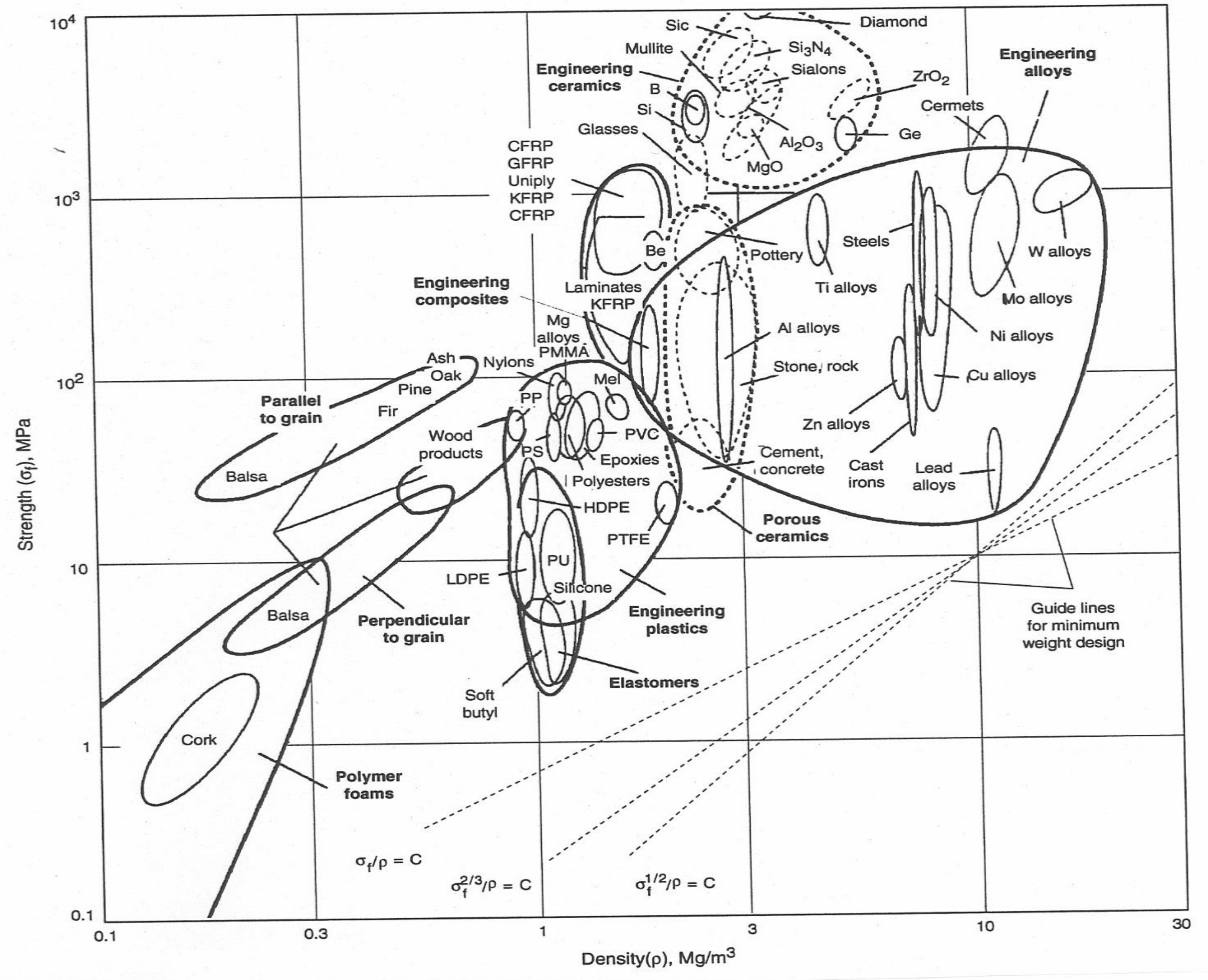


Fig.9.2(b)

Comparing and ranking alternatives I
Weighted properties method I

In this method each material requirement is assigned a certain weight, depending on its importance.

A weighted property value is obtained by multiplying the scaled value of the property by the weighting factor (α).

The weighted property values of each material are then summed to give a performance index (γ). The material with the highest performance index (γ) is optimum for the application.

$$B = \text{scaled property} = \frac{\text{numerical value of property x } 100}{\text{maximum value in the list}}$$

Comparing and ranking alternatives I
Weighted properties method II

For cost, corrosion loss, etc., a lower value is more desirable and the lowest value is rated as 100

$$B = \text{scaled property} = \frac{\text{minimum value in the list x 100}}{\text{numerical value of property}}$$

$$\text{Material performance index} = \gamma = \sum_{i=1}^{n} B_i \alpha_i$$

where i is summed over all the n relevant properties.

Comparing and ranking alternatives I
The Digital Logic Method

Table 9.3 Determination of the relative importance of goals using the digital logic method

Goals	Number of positive decisions N = n(n-1)/2										Positive decisions	Relative emphasis coefficient α
	1	2	3	4	5	6	7	8	9	10		
1	1	1	0	1							3	0.3
2	0				1	0	1				2	0.2
3		0			0			1	0		1	0.1
4			1			1		0		0	2	0.2
5				0			0		1	1	2	0.2
				Total number of positive decisions							10	$\Sigma\ \alpha = 1.0$

Comparing and ranking alternatives I Taking cost into consideration

Cost can be considered as one of the properties and given a weighting factor or considered separately as a modifier to the material performance index (γ).

In the cases where the material is used for space filling, cost can be introduced on per unit volume basis. A figure of merit (M) for the material can then be defined as:

$$M = \gamma/(C\ \rho)$$

C = total cost of the material per unit weight (stock, processing, finishing, ...etc)

ρ = density of the material.

Case study 9.2-Selecting the optimum material for a cryogenic storage tank

Materials requirements:

- used in cryogenic applications for liquefied nitrogen gas) must not suffer ductile-brittle transition at -196^oC
- Using stronger material gives thinner walls, which means a lighter tank, lower cool down losses, and easier to weld.
- Lower specific gravity gives lighter tank.
- Lower specific heat reduces cool down losses.
- Lower thermal expansion coefficient reduces thermal stresse.
- Lower thermal conductivity reduces heat losses.
- The cost of material and processing will be used as a modifier to the material performance index.

Table 9.4 Application of digital logic method to cryogenic tank problem

Property	**Decision number**																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Toughness	**1**	**1**	**1**	**1**	**1**	**1**															
Yield strength	**0**						**1**	**0**	**0**	**1**	**1**										
Young's modulus		**0**					**0**					**0**	**0**	**0**	**1**						
Density			**0**					**1**				**1**				**1**	**1**	**1**			
Expansion				**0**					**1**				**1**			**0**			**1**	**1**	
Conductivity					**0**					**0**				**1**			**0**		**0**		**0**
Specific heat						**0**					**0**				**0**			**0**		**0**	**1**

Table 9.5 Weighting factors for cryogenic tank

Property	**Positive decisions**	**Weighting factor**
Toughness	**6**	**0.28**
Yield strength	**3**	**0.14**
Young’s modulus	**1**	**0.05**
Density	**5**	**0.24**
Expansion	**4**	**0.19**
Conductivity	**1**	**0.05**
Specific heat	**1**	**0.05**
Total	**21**	**1.00**

Table 9.6 Properties of candidate materials for cryogenic tank

Material	1	2	3	4	5	6	7
	Toughness index[a]	Yield strength (MPa)	Young's modulus (GPa)	Specific gravity	Thermal expansion[b]	Thermal conductivity[c]	Specific heat[d]
Al 2014-T6	75.5	420	74.2	2.8	21.4	0.37	0.16
Al 5052-O	95	91	70	2.68	22.1	0.33	0.16
SS 301-FH	770	1365	189	7.9	16.9	0.04	0.08
SS 310-3/4H	187	1120	210	7.9	14.4	0.03	0.08
Ti-6Al-4V	179	875	112	4.43	9.4	0.016	0.09
Inconel 718	239	1190	217	8.51	11.5	0.31	0.07
70Cu-30Zn	273	200	112	8.53	19.9	0.29	0.06

[a] **Toughness index, TI, is based on UTS, yield strength YS, and ductility e, at -196 °C (-321.8 °F)**

$$\mathrm{TI} = (\mathrm{UTS}+\mathrm{YS})e/2$$

[b] **Thermal expansion coefficient is given in 10^{-6}/ °C. The values are averaged between RT and -196 °C.**

[c] **Thermal conductivity is given in cal/cm^2/cm/ °C /s.**

[d] **Specific heat is given in cal/g/°C. The values are averaged between RT and -196 °C.**

Table 9.7 Scaled values of properties and performance index

Material	Scaled properties							Performance index (γ)
	1	2	3	4	5	6	7	
Al 2014-T6	10	30	34	96	44	4.3	38	42.2
Al 5052-O	12	6	32	100	43	4.8	38	40.1
SS 301-FH	100	100	87	34	56	40	75	70.9
SS 310-3/4H	24	82	97	34	65	53	75	50.0
Ti-6Al-4V	23	64	52	60	100	100	67	59.8
Inconel 718	31	87	100	30	82	5.2	86	53.3
70Cu-30Zn	35	15	52	30	47	5.5	100	35.9

Table 9.8 Cost, figure of merit, and ranking of candidate materials

Material	Relative cost [a]	Cost of unit strengthx100	Performance index	Figure of merit	Rank
Al 2014-T6	1	0.67	42.2	62.99	2
Al 5052-O	1.05	3.09	40.1	12.98	6
SS 301-FH	1.4	0.81	70.9	87.53	1
SS 310-3/4H	1.5	1.06	50.0	47.17	3
Ti-6Al-4V	6.3	3.20	59.8	18.69	4
Inconel 718	5.0	3.58	53.3	14.89	5
70Cu-30Zn	2.1	8.96	35.9	4.01	7

Comparing and ranking alternatives II
Limits on properties method I

The performance requirements are divided into three categories:

- lower limit properties;
- upper limit properties;
- target value properties.

The limits can be used for eliminating unsuitable materials from a data bank.

After the elimination stage, the limits on properties method can then be used to optimize the selection from among the remaining materials.

Limits on properties method II

Merit parameter, m, is calculated for each material:

$$m = \left(\sum_{i=1}^{n_l} \alpha_i \frac{Y_i}{X_i} \right)_l + \left(\sum_{j=1}^{n_u} \alpha_j \frac{X_i}{Y_i} \right)_u + \left(\sum_{k=1}^{n_t} \alpha_k \left| \frac{X_k}{Y_k} - 1 \right| \right)_t \qquad (9.8)$$

l, u, and t stand for lower limit, upper limit, and target values

n_l, n_u and n_t are numbers of lower limit, upper limit and target values

α_i, α_j and α_k are weighs of lower limit, upper limit, and target values.

X_i, X_j and X_k are candidate material lower limit, upper limit, and target value properties.

Y_i, Y_j and Y_k are specified lower limits, upper limits, and target values.

The lower the value of the merit parameter, m, the better the material.

Limits on properties method II
Case study 9.3 - Selecting an insulating material for a flexible electrical cable

Rigid requirements: flexibility, which eliminates all ceramics.

The electrical and physical design requirements are:

1. Dielectric strength: a lower limit property > 10,000 volts/mm.
2. Insulating resistance: a lower limit property > 10^{14} ohm/cm.
3. Dissipation factor: an upper limit property < 0.0015 at 60 Hz.
4. Dielectric constant: an upper limit requirement < 3.5 at 60 Hz.
5. Thermal expansion is a target value is taken as $2.3\text{x}10^{-5}/^{o}\text{C}$.

Table 9.9 Properties of some candidate insulating materials

Material	**Dielectric strength (V/mm)**	**Volume resistance (ohm/cm)**	**Dissipation factor (60 Hz)**	**Dielectric constant (60 Hz)**	**Thermal expansion (10^{-5}/^{o}C)**	**Relative cost**[a]
PTFE	**14,820**	**10^{18}**	**0.0002**	**2.1**	**9.5**	**4.5**
CTFE	**21,450**	**10^{18}**	**0.0012**	**2.7**	**14.4**	**9.0**
ETFE	**78,000**	**10^{16}**	**0.0006**	**2.6**	**9.0**	**8.5**
Polyphenylene oxide	**20,475**	**10^{17}**	**0.0006**	**2.6**	**6.5**	**2.6**
Polysulfone	**16,575**	**10^{14}**	**0.0010**	**3.1**	**5.6**	**3.5**
Polypropylene	**21,450**	**10^{16}**	**0.0005**	**2.2**	**8.6**	**1.0**

Table 9.10 Weighting factors for an electrical insulator

Property	Decision number															Total	Weighting factor
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Dielectric strength	0	1	1	0	1											3	0.20
Volume resistance	1					1	1	1	1							5	0.33
Dissipation factor		0				0				1	1	0				2	0.13
Dielectric constant			0				0			0			1	0		1	0.07
Thermal expansion				1				0			0		0		0	1	0.07
Cost					0				0			1		1	1	3	0.20
																15	1.00

Table 9.11 Evaluation of insulating materials

Material	Merit parameter (*m*)	Rank
PTFE	0.78	3
CTFE	1.07	6
ETFE	0.81	5
Polyphenylene oxide	0.66	1
Polysulfone	0.78	3
Polypropylene	0.66	1

Comparing and ranking alternatives III
Case study 9.4 - Using AHP to select the optimum material for a roof truss I

Material performance requiremens:

- high strength (σ),
- high elastic modulus (E),
- low density (ρ)
- low cost (C). The candidate materials are:

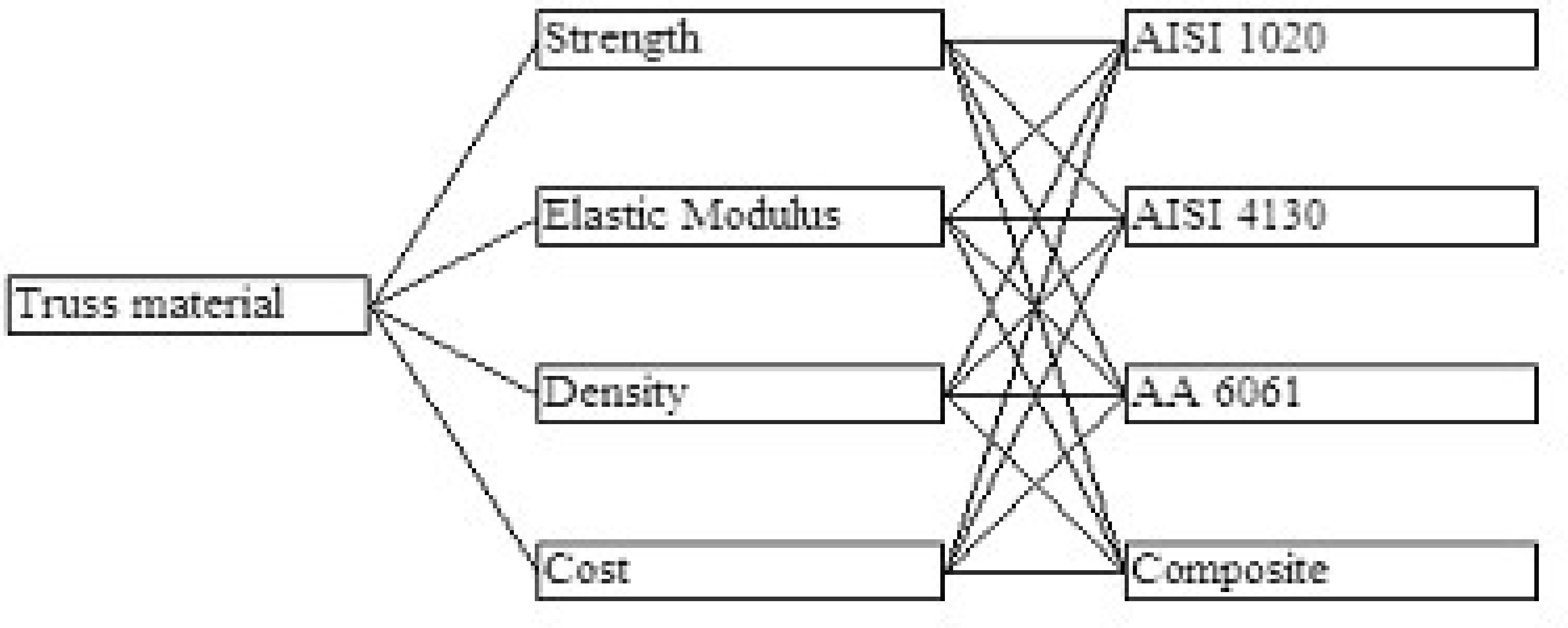
Case study 9.4 - Using AHP to select the optimum material for a roof truss II

Table 9.12 Properties of the candidate materials for the truss

	Yield strength (σ) MPa	Elastic modulus (E) GPa	Density (ρ) g/cc	Cost category (C)*
AISI 1020	280	210	7.8	5
AISI 4130	1520	212	7.8	3
AA 6061	275	70	2.7	4
Epoxy-70% glass fabric	1270	28	2.1	2

* 5, very inexpensive; 4, inexpensive; 3, moderate price; 2, expensive; 1, very expensive

Case study 9.4 - Using AHP to select the optimum material for a roof truss III



Case study 9.4 - Using AHP to select the optimum material for a roof truss IV

Table 9.13 Pairwise comparison of material requirements

	σ	E	ρ	C
σ	1	1/5	1/3	1/2
E	5	1	2	4
ρ	3	1/2	1	3
C	2	1/4	1/3	1

Case study 9.4 - Using AHP to select the optimum material for a roof truss V

Table 9.14 Calculation of Weights

	σ	E	ρ	C	Average/weight	Consistency measure
σ	0.091	0.102	0.091	0.059	0.086	4.02
E	0.455	0.513	0.545	0.471	0.496	4.07
ρ	0.273	0.256	0.273	0.353	0.289	4.09
C	0.182	0.128	0.091	0.118	0.129	4.04
Total/Average	1.001	0.999	1.000	1.001	1.000	4.055

Case study 9.4 - Using AHP to select the optimum material for a roof truss VI

Table (9.15) Random Index (*RI*) as a function of the number of properties (n)

n	2	3	4	5	6	7	8	9	10
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 9.16 Results of AHP for the truss materials

Material	Rank	Score	Major contributions to the score			
			σ	E	ρ	C
AISI 1020	2	0.286		77%		23%
AISI 4130	1	0.293	16%	76%		8%
AA 6061	3	0.231		22%	59%	19%
Composite	4	0.191	20%		80%	

Reaching final decision
Case study 9.5- Selecting the optimum material for a sailing-boat mast component I

Problem: Select the least expensive component for a sailing-boat mast in the form of a hollow cylinder

Load: Compressive axial forces of 153 kN in addition to mechanical impact and spray of water.

Length 1000 mm

Outer diameter < 100 mm,

Inner diameter > 84 mm

Mass should < 3 kg.

Small holes are needed for assembly to other components.

Case study 9.5- Selecting the optimum material for a sailing-boat mast component II

Material performance requirements

- High fracture toughness is a rigid requirement and will be used for initial screening of materials.
- High yield strength.
- High elastic modulus to resist local and global buckling.
- Good corrosion resistance.
- Use a factor of safety of 1.5 for improved i.e. the working axial force is taken as 230 kN.

Case study 9.5- Selecting the optimum material for a sailing-boat mast component III

Initial screening of materials

- The requirement for fracture toughness of the material is used to eliminate ceramic materials.
- Because of the limitations on OD and ID, cross section should not exceed 2300 mm^2.
- To avoid yielding under the axial load, the yield strength > 100 MPa.

Table (9.17) Properties of Sample Candidate Materials.(Based on Farag and El-Magd)

Material	Yield Strength (MPa)	Elastic Modulus (GPa)	Specific Gravity	Corrosion Resistance*	Cost Category**
AISI 1020 (UNS G10200)	280	210	7.8	1	5
AISI 1040 (UNS G10400)	400	210	7.8	1	5
ASTM A242 type1 (UNS K11510)	330	212	7.8	1	5
AISI 4130 (UNS G41300)	1520	212	7.8	4	3
AISI 316 (UNS S31600)	205	200	7.98	4	3
AISI 416 Ht. Treated (UNS S41600)	440	216	7.7	4	3
AISI 431 Ht. Treated (UNS S43100)	550	216	7.7	4	3
AA 6061 T6 (UNS A96061)	275	69.7	2.7	3	4
AA 2024 T6 (UNS A92024)	393	72.4	2.77	3	4
AA 2014 T6 (UNS A92014)	415	72.1	2.8	3	4
AA 7075 T6 (UNS A97075)	505	72.4	2.8	3	4
Ti-6Al-4V	939	124	4.5	5	1
Epoxy-70% glass fabric	1270	28	2.1	4	2
Epoxy-63% carbon fabric	670	107	1.61	4	1
Epoxy-62%aramid fabric	880	38	1.38	4	1

* 5 Excellent, 4 Very good, 3 Good, 2 Fair, 1 Poor

** 5 Very inexpensive, 4 Inexpensive, 3 Moderate price, 2 Expensive, 1 Very expensive

Table (9.18) Properties of Sample Candidate Materials

Material	Specific Strength (MPa)	Specific Modulus (GPa)	Corrosion Resistance*	Cost Category**
AISI 1020 (UNS G10200)	35.9	26.9	1	5
AISI 1040 (UNS G10400)	51.3	26.9	1	5
ASTM A242 type1 (UNS K11510)	42.3	27.2	1	5
AISI 4130 (UNS G41300)	194.9	27.2	4	3
AISI 316 (UNS S31600)	25.6	25.1	4	3
AISI 416 Ht. Treated (UNS S41600)	57.1	28.1	4	3
AISI 431 Ht. Treated (UNS S43100)	71.4	28.1	4	3
AA 6061 T6 (UNS A96061)	101.9	25.8	3	4
AA 2024 T6 (UNS A92024)	141.9	26.1	3	4
AA 2014 T6 (UNS A92014)	148.2	25.8	3	4
AA 7075 T6 (UNS A97075)	180.4	25.9	3	4
Ti-6Al-4V	208.7	27.6	5	1
Epoxy-70% glass fabric	604.8	28	4	2
Epoxy-63% carbon fabric	416.2	66.5	4	1
Epoxy-62%aramid fabric	637.7	27.5	4	1

* 5 Excellent, 4 Very good, 3 Good, 2 Fair, 1 Poor

** 5 Very inexpensive, 4 Inexpensive, 3 Moderate price, 2 Expensive, 1 Very expensive

Case study 9.5- Selecting the optimum material for a sailing-boat mast component VI

Table (9.19) Weighting Factors

Property	Specific Strength (MPa)	Specific Modulus (GPa)	Corrosion Resistance	Relative Cost
Weighting Factor (α)	0.3	0.3	0.15	0.25

Table (9.20) Calculation of the Performance Index

Material	Scaled Specific Strength * 0.3	Scaled Specific Modulus * 0.3	Scaled Corrosion Resistance * 0.15	Scaled Relative Cost * 0.25	Performance Index (γ)
AISI 1020 (UNS G10200)	1.7	12.3	3	25	42
AISI 1040 (UNS G10400)	2.4	12.3	3	25	42.7
ASTM A242 type1 (UNS K11510)	2	12.3	3	25	42.3
AISI 4130 (UNS G41300)	9.2	12.3	6	15	42.5
AISI 316 (UNS S31600)	1.2	11.3	12	15	39.5
AISI 416 Ht. Treated (UNS S41600)	2.7	12.7	12	15	42.4
AISI 431 Ht. Treated (UNS S43100)	3.4	12.7	12	15	43.1
AA 6061 T6 (UNS A96061)	4.8	11.6	9	20	45.4
AA 2024 T6 (UNS A92024)	6.7	11.8	9	20	47.5
AA 2014 T6 (UNS A92014)	7	11.6	9	20	47.6
AA 7075 T6 (UNS A97075)	8.5	11.7	9	20	49.2
Ti-6Al-4V	9.8	12.5	15	5	42.3
Epoxy-70% glass fabric	28.4	12.6	12	10	63
Epoxy-63% carbon fabric	19.6	30	12	5	66.6
Epoxy-62%aramid fabric	30	12.4	12	5	59.4

Case study 9.5- Selecting the optimum material for a sailing-boat mast component VIII

The component must resist 4 possible failure modes:

1. Condition for yielding: $F/A < \sigma_y$ Eq (9.11)

   σ_y is yield strength

   F is external working axial force,

   A is cross sectional area

2. Condition for local buckling: $F/A < 0.121\ E\ S/D$ Eq (9.12)

   D is outer diameter of the cylinder,

   S is wall thickness of the cylinder,

   E is elastic modulus

Case study 9.5- Selecting the optimum material for a sailing-boat mast component IX

3. Condition for global buckling:

$\sigma_y > F/A\,[1+(L\,D\,A/1000\,\mathrm{I})\sec\{(F/EI)^{1/2}\,L/2\}]$ Eq (9.13)

I is second moment of area,

L is length of the component

4. Condition for fiber buckling: $F/A < [E_m/4(1+\upsilon_m)(1-V_f^{1/2})]$

Eq (9.14)

E_m is elastic modulus of the matrix material,

υ_m is Poisson's ratio of the matrix material,

V_f is volume fraction of fibers parallel to loading direction

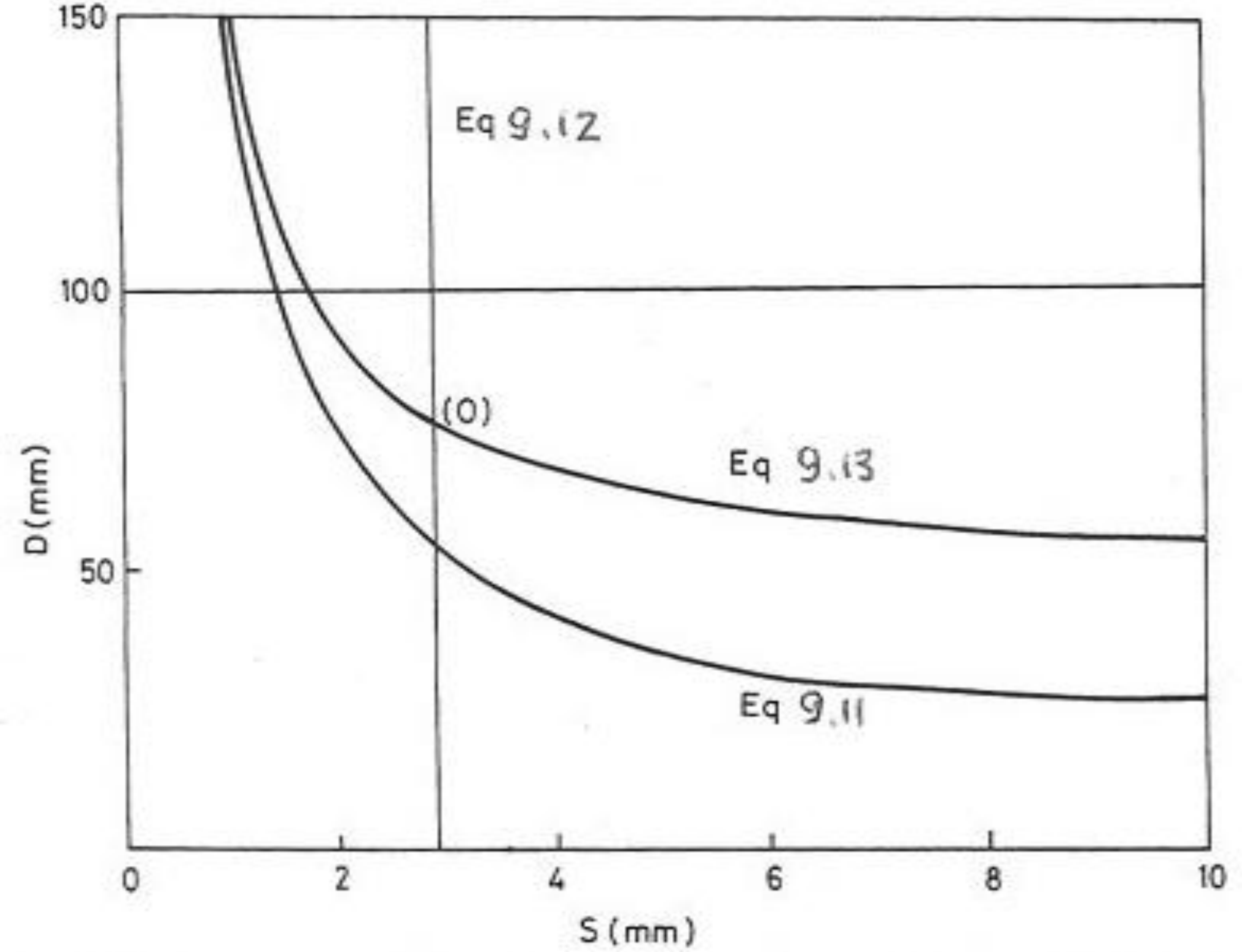


Figure 9.4 Design range as predicted by Eqs. 9.11–13 for AA 7075 aluminum alloy. (Reprinted from *Materials and Design*, **13,** M. M. Farag and E. El-Magd, An Integrated Approach to Product Design, Materials Selection, and Cost Estimation, 323–327, © 1992, with permission from Elsevier Science.)

Table (9.21) Designs Using Candidate Materials With Highest Performance Indices.

(Based on Farag and El-Magd)

Material	D_a (mm)	S (mm)	A (mm^2)	Mass (kg)	Cost/kg ($)	Cost of Component ($)
AA 6061 T6 (UNS A96061)	100	3.4	1065.7	2.88	8	23.2
AA 2024 T6 (UNS A92024)	88.3	2.89	801.1	2.22	8.3	18.4
AA 2014 T6 (UNS A92014)	85.6	2.89	776.6	2.17	9	19.6
AA 7075 T6 (UNS A97075)	78.1	2.89	709.1	1.99	10.1	20
Epoxy-70% glass fabric	78	4.64	1136.3	2.39	30.8	73.6
Epoxy-63% carbon fabric	73.4	2.37	546.1	0.88	99	87.1
Epoxy-62%aramid fabric	75.1	3.99	941.6	1.30	88	114.4

Chapter 9: Summary I

1. It is desirable for product development teams to adopt the concurrent engineering approach, where materials and manufacturing processes are considered in the early stages of design and are more precisely defined as the design progresses from the concept to the embodiment and finally the detail stage.

2. Stages of the selection process are:
   - analysis of the performance requirements and creating alternative solutions,
   - initial screening of solutions,
   - comparing and ranking alternative solutions, and
   - selecting the optimum solution.

Chapter 9: Summary II

3. Methods for initial screening:
   - Cost per unit property
   - Ashby’s selection charts,
   - Dargie’s method, and
   - Esawi and Ashby’s method

4. Ranking alternatives:
   - Weighted property method
   - The limits on properties method
   - The Analytic Hierarchy Process (AHP)

Chapter 9: Summary III

5. Reaching final decision

- After ranking of alternatives, candidates that have the most promising performance indices can each now be used to develop a detail design.
- Each detail design will exploit the points of strength of the material, avoid the weak points, and reflect the requirements of the manufacturing processes needed for the material.
- After completing the different designs, solutions are then compared, taking the cost elements into consideration in order to arrive at the optimum design-material-process combination.

Chapter 9: Summary IV

Sources of material information

- Reliable and consistent sources of materials information are essential for successful materials selection.
- More detail and higher accuracy of information are needed as the selection process progresses from the initial screening to the final selection stage.
- Several databases and Internet sources are cited for these purposes.