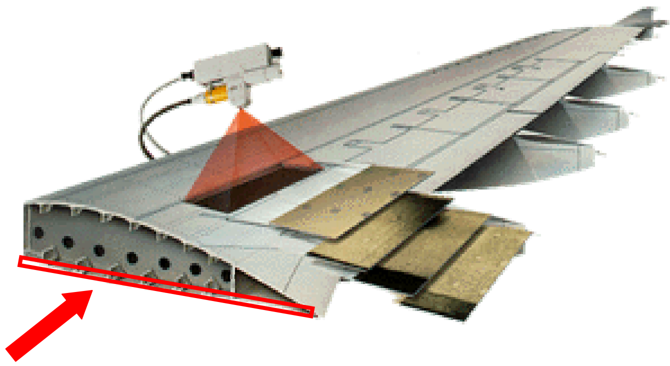
Case Study:

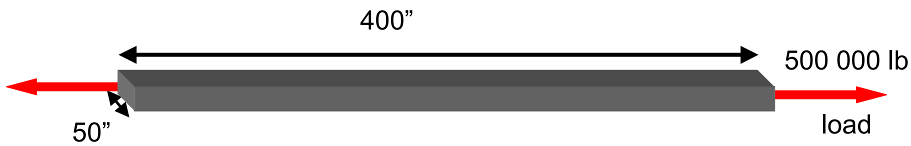
Materials Selection - Designing a Lower Wing Span for a Plane

MMat 380



The aluminum skin is applied
to the wing sections. The wing-mounted
fuel tanks will occupy a place in this section.

Question 1 - Save Weight



- Wing dimensions
  Length 400 in
  Width 50 in
  Thickness ??

Determine material weight required to carry 500 000 lb tension load

Alloy	Allowable design yield stress (ksi)	Density (lb/in³)	Weight, lb
7075-T651	69	0.101	
7055-T7751	86	0.102	
2024-T351	48	0.101	
2324-T39	62	0.100	
Ti-6Al-4V	120	0.160	
4340M	226	0.283	

Rank materials in order of preference (i.e., minimum weight)

1	
2	
3	
4	
5	
6	

Question 2 - Damage Tolerance

- The lower wing is subject to fatigue loading. If a fatigue crack occurs in the skin panel, calculate the critical crack length for the allowable design yield stress
- Fracture toughness Equation

$$K = \sigma\sqrt{\pi a}$$

K = Material fracture toughness (ksi*in$^{1/2}$)

σ = Applied stress (ksi)

a = Critical flaw size (=1/2 crack length for flat plate) (in)

Question 2 - Damage Tolerance

Alloy	Allowable design yield stress (ksi)	Allowable fracture toughness, ksi $(in)^{1/2}$	2a Critical crack length, (in)
7075-T651	69	67	
7055-T7751	86	85	
2024-T351	48	141	
2324-T39	62	142	
Ti-6Al-4V	120	150	
4340M	275	100	

Question 3 - Damage tolerance and weight savings

The airlines and Boeing have determined it is unrealistic to insect for small cracks in the lower wing. At 2-in long, cracks can be easily detected by fuel leakage - an obvious indicator.

a) Redefine the allowable operating stress for a 2-in crack

b) Calculate the weight impact of this new allowable

Question 3 - Damage tolerance and weight savings

Alloy	Allowable fracture toughness, ksi (in)$^{1/2}$	Allowable design stress for 2-in crack - use yield stress if lower, ksi	Weight, lb
7075-T651	67		
7055-T7751	85		
2024-T351	141		
2324-T39	142		
Ti-6Al-4V	150		
4340M	100		

Rank materials in order of preference

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Question 4 - Corrosion Prevention

- The materials you have chosen have widely varying corrosion performance. General corrosion and stress corrosion are of particular concern
- Determine the allowable design stress and weight impact to avoid stress corrosion cracking for a 2-in crack

Question 4 - Corrosion Prevention

Alloy	Allowable corrosion toughness design threshhold (ksi in$^{1/2}$)	Allowable design stress for 2-in crack - use yield stress if lower, ksi	Weight, lb
7075-T651	Generally not susceptible in Long Transverse Direction		
7055-T7751			
2024-T351			
2324-T39			
Ti-6Al-4V	30		
4340M	15		

Question 5 - Cost Effectiveness

- Hopefully you have selected 2024 or 2324 for your lower skin material. Your program is willing to pay $200 to save 1lb of weight. Determine if you can justify 2324-T39 or a new Al-Li alloy that has equal properties to 2024 but is 4% less dense (i.e., saves 4% of the weight required for 2024).
- What about a composite material that results in a 25% weight savings as compared to 2024
- Which materials meet your program's guidelines ?

Question 5 - Cost Effectiveness

Alloy	Raw material cost increase over 2024-T3	Weight savings over 2024-T3	Ratio of material purchased to that flown away (B to F ratio)	$/lb of wt. saved
2324	$1.00/lb		2.0	
Al-Li	$6.00/lb		2.0	
Composite	$50.00/lb		1.5	

$$\$/\text{lb weight saved} = \frac{(\text{Material cost increase})(\text{Fly-away weight})(\text{B to F ratio})}{\text{Weight savings}}$$