Problem M19

For wing spars bending loads are the major design driver.

For engine disks the power density (and hence thrust) scales with the blade tip speed (V) squared. The centrifugal stress in a spinning disk is proportional to the density of the material used (ρ) and the tip speed squared, and to a good approximation this is given by: $\sigma \approx \frac{3}{8}\rho V^2$. Thus engines are designed to develop as much thrust as the material strength will allow.

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a) If wing spars and engine disks are to be designed to a criterion such that there is no permanent deformation at the limit stress (i.e. yield does not occur). Determine the material selection criterion for (i) wing spars and (ii) turbine disks.
b) Rank the materials below according to their suitability for each application.
c) Airframe structures typically operate at about 40% of the limit load during normal operations, which provides a margin for unexpected maneuver loads and gust loading. Engine disks regularly experience about 90% of their design limit load, as their loads are much more predictable due to the dominance of the centrifugal loading. Determine the critical crack size in your top ranked materials for each application under normal operating loads.
d) Hence comment on the feasibility of using a damage tolerant design approach in each case.

Material	Density Kg/m^3	Young's Modulus (GPa)	Yield Stress (MPa)	Fracture Toughness MPa√m
Al Alloy 2024 (T3)	2800	70	345	44
Al Alloy 7075 (T651)	2800	70	495	24
Ti Alloy Ti-6Al-4V	4510	110	910	50
Steel 17-7 PH (Stainless)	8000	193	1435	77
Medium Carbon Steel	7800	208	260	54