Unit II Examination

~~**EMA 4714 - Materials Selection and Failure Analysis**~~ ~~**KEY**~~

~~**Monday, April 7, 2003**~~

I. Statistics and Probability [20 points]

1. [10 points] A steel [$E = 30x10^6$ psi] cantilever beam of length 10 ft is required to support a concentrated load at its free end whose mean value is 500 lb and whose standard deviation is 50 lb. If the cross section of the beam is rectangular with a 2 inch width, how thick should the beam be so that there is a 99.9% probability that the deflection at the free end is less than 3 inches?

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Assume a normally distributed population of applied loads whose mean [m] is 500 lbs with a standard deviation [s] of 50 lbs. Let x be a load which produces a beam deflection of 3 inches. The standard normal variable, z, for 99.9% [0.999] of applied loads producing beam deflections of <3 inches is +3.090 and equals [x-m]/s; x = 654.5 lbs. For d = $FL^3/3EI$, where $I = bt^3$, $t^3 = [4*654.5*(10*12)^3/[3*2*30x10^6] = 25.13$, t = 2.93 inches

2. [10 points] The mean and standard deviation for the lifetime [in hours] of computer hard drives A and B are A(bar) = 40,000 [$\sigma_A = 6000$] and B(bar) = 50,000 [$\sigma_B = 8000$]. Which drive is more likely to last at least 30,000 hours? Which one is more likely to last at least 60,000 hours?

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For P_A(=30000), z = [30000-40000]/6000 = -1.6667 or 0.0475, 4.75% fail, 95.25% pass
For P_B(=30000), z = [30000-50000]/8000 = -2.5 or 0.0072, 0.72% fail, 99.38% pass, B better.

For P_A(=60000), z = [60000-40000]/6000 = 3.333 or 0.99957, 99.957% fail, 0.043% pass
For P_B(=60000), z = [60000-50000]/8000 = 1.25 or 0.8944, 89.44% fail, 10.56% pass, B better.

II. Engineering Economics [10 points]

Your client purchased a mainframe computer three years ago for $30,000. Now they are considering expanding their computing capability by either buying a new computer or adding components to the existing one. Additional components can be purchased for the present computer at a cost of $10,000. You estimate that the improved computer will have a life of 5 years with an annual operations, maintenance and repair [OMR] cost of $2500. It is not expected to have any salvage value at the end of the period. A second option is to buy a new ABC computer at a cost of $35,000. This unit will have an expected life of $15 years, an annual OMR cost of $1500, and a salvage value of $5000 [FW]. Another option is to purchase a new XYZ computer for $27,000. For this computer, the expected life is 10 years, with an annual OMR cost of $2000, and a salvage value of $3000. The existing computer has a trade-in value of $5000 if either of the new computers is purchased. All three computers have the same computational capacity. Assuming an interest rate of 10%, which alternative would you advise your client to choose? State all assumptions and conditions used in performing your analysis.

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Ignore $30,000 cost of mainframe computer - without upgrades, does it have value? Not for present owner, that is clear, but for someone else? Anyway, I would let this go.....

PW(1) = -10.0-2.5(P/A,10,5) = -10-2.5(3.79079) = -$19.5k
A(1) = -19.5(A/P,10,5) = -19.5/(P/A,10,5) = -19.5/3.79079 = -$5.14k

PW(2) = -(35.0-5.00)-1.5(P/A,10,15)+5.0(P/F,10,15) = -30.0-1.5(7.60608)+5.0(0.23939)
= -$40.2
A(2) = -40.2(A/P,10,15) = -40.2/(P/A,10,15) = -40.2/7.60608 = -$5.29k

PW(3) = -(27.0-5.0)-2.0(P/A,10,10)+3.0(P/F,10,10) = -22.0-2.0(6.14457)+3.0(0.388554) =
= -$33.1k

A(3) = -33.1(A/P,10,10) = -33.1/(P/A,10,10) = -33.1/6.14457 = -$5.39

Option 1 best

III. Failure Analysis and Product Liability [10 points]

Recently I spoke with you of a case involving a cooling coil in a motor home refrigerator. In sifting through the ashes from the fire which consumed the motor home, a section of steel tubing [cooling coil] had a longitudinal crack adjacent to a weldment used to attach a resistance heating coil to the refrigeration coil. It became the position of plaintiffs that this crack allowed refrigerant to escape from the system which subsequently became the fuel for the fire which consumed the motor home. In their opinion, the occurrence of this crack was the result of a design or manufacturing defect on the part of the manufacturer. Plaintiff's expert was convinced that this failure was the result of poor engineering design in that cyclic stresses due to repetitive heat/cooling cycles led to a slow grow of the crack until leakage occurred.

The tubing was 1.0 inch in diameter with a wall thickness of 0.0625 inches. The material was an AISI 1010 steel, $E = 30 \times 10^6$ psi, $\sigma_y = 26{,}100$ psi. $K_{1c} = 50$ ksi*in$^{1/2}$. The refrigerant was contained within the cooling coil at 600 psi [at least before the leak it was]. Upon sectioning the tubing the crack was found to have been 1.25 inches long in the inside wall and 0.50 inches long on the outside wall.

Based on this information, discuss what it is that plaintiffs will have to prove if they are to prevail. In addition, based on the facts as I have stated them and the material specifications and properties provided, offer your own opinion as to the merits of the plaintiff's case.

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A crack in a cooling coil tube, even though located in the vicinity of where the fire started, will have to possess a causal relationship between the consequences arising from the leak and the damages arising from the fire. A few of the things that plaintiffs have the burden of proving:

1. **The crack was the result of a defective condition of the tube**
2. **The crack, and subsequent leak occurred prior to the fire**
3. **The substance released contributed to the fire [was combustible].**

As for the crack, the size of the crack is at issue here. A leak, and subsequent loss in the internal pressure which makes the crack grow, will occur at that point in time when the crack length equals the wall thickness of the tube.

s(hoop) = pr/t = 600*0.5/0.0625 = 4800 psi; for s_y = 26,100, S_F = 26100/4800 = 5.43, extremely high, not a question of poor choice in material.

For a_{crit} = 0.0625, $K_{1c} = Ys_f(pa)^{1/2}$; for Y = 1, K_{1c}(crit) = 11.56 ksi*in$^{1/2}$; since the K_{1c} for the subject steel is far greater than this minimum, tubing would have had to have leaked, releasing internal stress and preventing slow crack growth to the dimensions measured. Fracture probably occurred as a result of the fire rather than being the cause for it. At elevated temperatures s_y is substantially decreased.