Engineering Ethics Cases with Numerical Problems

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Mechanical Engineering Case 4

Light Duty Step Ladder: Which Way Should You Lean?

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Suggested Courses:

Mechanics of Materials

Level:

Sophomore & Junior

I. Narrative

You are a newly licensed engineer with a company that makes a variety of consumer products. A newly-designed light duty step ladder has been proposed which can be marketed very competitively, and you are asked to evaluate the design. The design is shown in the drawings below. The back legs are made of 0.10" aluminum sheet bent into a "C" shape cross section. The brace between the legs is made of 0.75" od aluminum tube with a wall thickness of 0.05". Your first step is to consult the relevant government standards, where you find that for light duty ladders that the following test is prescribed:

The ladder is tested while lying on its side on a flat, level surface. A weight of fifty pounds is hung on the end of the back leg (the one which is above the surface in the test position). To pass specifications the deflection of the end of that leg must not exceed 0.25 inches. In addition, when the weight is removed the ladder leg must return to its original position with "no apparent permanent distortion" You find no other regulations that seem to apply.

II. Questions

1. To perform a very conservative prediction of the probability of the design meeting the requirements, you decide to treat the effect of the lower brace as merely a very stiff (rigid) support at the position of the cross piece, 15" from the end of the leg. Perform this analysis. What deflection of the leg end is predicted? Do you expect any permanent deformation? Why or why not? Assume a yield stress of 15,000 psi..

2. Is this indeed a conservative analysis? What additional stiffening effect can you really expect from the brace?

3. You express your safety concerns, and the boss says that your concern is not really a problem and that the design more than meets specs. He says that the government knows what it's doing , so the failure mode addressed by the specs must be the critical one. He insists that the design is fine. And besides, the plant is already tooled up for production. Given that there are the following models of engineering: Malpractice-a minimalist approach to cover yourself leagaly, Due Care-to take reasonable precautions in your designs, and Good Works-to go beyond the call of duty and work extra nights to meet higher standards than required in order to produce the safest product available. What model of engineering is espoused by your employer? How could you meet the other models of engineering?

4. Thought provoking question: Assuming all internal company issues can be resolved, do you have any professional responsibility to try to get the government to adopt more meaningful test specifications?

III. Numerical Solutions

Section modulus for leg: I = .036 in **4 for tube I = .0599 in **4

For cantilever beam with end load: defl = (P*L**3)/3*E*I max bending stress = P*L*c/I

For leg cantilevered at lower crossbrace: equiv. spring constant = 320 lb/in, deflect at 50# load = 0.156", and max stress = 14,850 psi. These values are below the allowable .25" and 15,000 psi, and, since the analysis is conservative, we expect the ladder to pass the prescribed test.

To model the lower brace as a spring, assume 15" cantilevers attached with rigid corners to 22" simple beam with end moments. This is NOT conservative since the corners will not be rigid. Equivalent spring constant = 83 lb/in. Leg as cantilever 55" long with this equivalent spring supporting it has total equivalent spring constant 89.5 lb/ in. Thus the ladder is much more flexible in the outward bending mode. A fifty pound load in the outward direction will produce a deflection of over half an inch, and a maximum stress at the upper brace attachment point of 50,000 psi. This will yield the aluminum, result in permanent deformation, and weaken the ladder.

IV. Sample Solutions to Ethical Question 3

The employer in this case seems to be supporting the malpractice model of engineering. All the manager is concerned with is meeting the specifications set forth by the government. This is a fairly minimalist approach which will cover the company legally. A due care model might be implemented if the manager were to realize that the government's specifications are not the safest available, and it would not be too difficult to produce the ladder under tougher specifications which would provide a safer product. A good works example would require more than simply producing a safe product. This is to go above and beyond the call of duty. An example would be to work on your own time as an engineer to raise the legal standards so that they will provide a safer product overall.