Column published in the January 2003 issue of the Industrial Product Finder, page 269.

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MACHINE DESIGN STUDIO

Harshwardhan Gupta's Design Tips–3

Saving On Weight

The old engineering joke goes that since the (Soviet) Russians had no market economy, and therefore no real costing departments, they simply sold their machinery by weight, and so they always designed heavy, heavier and heaviest machines.

Are we any different? From what I see around, not really! We take our cues from the Boiler Regulations, Elevator Safety Codes, (where over-design *is* required) and from really old machine design textbooks. Play safe - our mothers tell us. Invest safe - our fathers tell us. And design safe - our engineering professors tell us. So we play Very Safe, Much Safer and Absolutely Safest. Not only that, in most Indian languages, the word for better quality literally means 'heavy'! But safety, or quality, has absolutely nothing to do with weight!

No wonder our efforts to build a Light Combat Aircraft can barely take off the ground. We still see the heavier-is-better attitude among our machine users and even general public. This is old dinosaur-type baggage, and faster we shed it, lighter we all will feel, and faster we will evolve as an engineering nation.

Weight is no guarantee for better performance, or better quality, or a better design. Here are some Do's and Don'ts:

1. We often misjudge the strength and modulus of materials, and over-design everything as a routine. This kind of unthinking over-design results in unnecessarily heavy and unwieldy, and sometimes slow-because-of-heavy-inertia machines. Today, one can easily model the part in 3D in any of the popular CAD packages, and do a finite-element stress-strain analysis to arrive at the optimum. These analyses are commonly available as a service by various consultants and agencies. Even this is not necessary if the designer has a good judgment of a material's strengths.
2. By keeping more space between parts when less will do, results in a bulkier and large machine, and therefore a heavier machine. Very often, designers keep 20-30 mm space between moving parts, where even 1 mm is sufficient. This is just lack of confidence in their own detailing.
3. We also routinely keep everything adjustable. This often results in a heavier design. It is wasteful and not necessary.
4. Using heavy external covers and seals for bearings, when off-the-shelf sealed rolling bearings could directly be used. This is a leaf taken from railways and earthmovers.
5. In similar vein, designing oversized round flanges too results in a heavier design. Few designers realize that in most cases, any flange material outside the PCD is useless, so they may as well reduce the PCD to the minimum, then reduce the OD to the minimum, and have an equally strong but lighter design.
6. The same goes for using heavy sections for press- or shrink-fitting, where modern industrial adhesives could be used easily and safely and heavy sections could be avoided. (See Design tips #1, November 2002)
7. Many of our well-qualified machine designers work in the machine-tool industry, where heavy castings are absolutely necessary to achieve rigidity, sustained accuracies to microns, vibration absorption. When they shift to other industries, many unfortunately bring this baggage into their new design office. High-speed packaging machines, high-performance piece-handling systems, etc., do not need such high rigidity, and can be designed much lighter.

8. Where torsional rigidity is required, a closed section (rectangular, square or round tubes) is many times stronger than an open section (beams, channels, angles) of the same weight-per-metre.
9. Many machine frames (not machine-tool frames) can be made in light sheet metal with some insightful designing. I have redesigned machines where I brought the frame weight down from 850 Kg to 120 Kg, and actually ended up having a *cheaper* and *more* rigid frame.
10. When you change over from cast-iron to steel sections or steel plate construction, you can make the part much lighter, as the cast-iron's ruling section (minimum thickness) was decided by the (molten) metal flow limitations, not by strength.
11. Making a sheet metal structure curved (like a cylinder), especially curved in two axes (like a dome) immediately results in enormous rigidity, so the sheet thickness can be brought down. In other words, a cylindrical box of sheet metal can support far more weight than a square box. A modern car is a perfect example of this concept.
12. Sheet-metal hat-sections welded to flat sheets make for very strong light-weight structures. Just look at the underside of a modern car's bonnet for proof. Same goes for the car body too.
13. Another sure-fire way to reduce weight, and costs, is to judiciously estimate the real power required to drive the machine. Does that cute little conveyor really need a 1HP motor? Does that packaging machine need a fat 3HP motor to drive it? Look for areas where power is being wasted. Fix those, then actually try the machine with a motor of $1/4^{th}$ the original power rating. I can confidently tell you that in 95% cases, it will run beautifully in all conditions. Now you can redesign the drives, shafts, couplings, gearboxes, bearings, etc. for that reduced transmitted power and make the whole machine substantially lighter.
14. Using a more expensive but far stronger material (or a material with a higher modulus) combined with good design can actually save money. Do think on those lines too.

Do not listen to old wives' tales about heavier being better. How often have you seen parts breaking or failing because they were not heavy enough? We cannot afford to waste raw material just because we are not sure of our design capabilities.

The Railways are often held up as an example of good design. Yes, locomotives need to be heavy as otherwise their wheels will slip at full power. Unknown to most of us, diesel and electric locomotives are actually weighted down with tonnes and tonnes of cast-iron nuggets, called ballast. But are we designing locomotives here? Do not design a dinosaur, or it will eat you alive in the end!

Next Month: Saving on Raw-Material Costs

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