

## High Tension

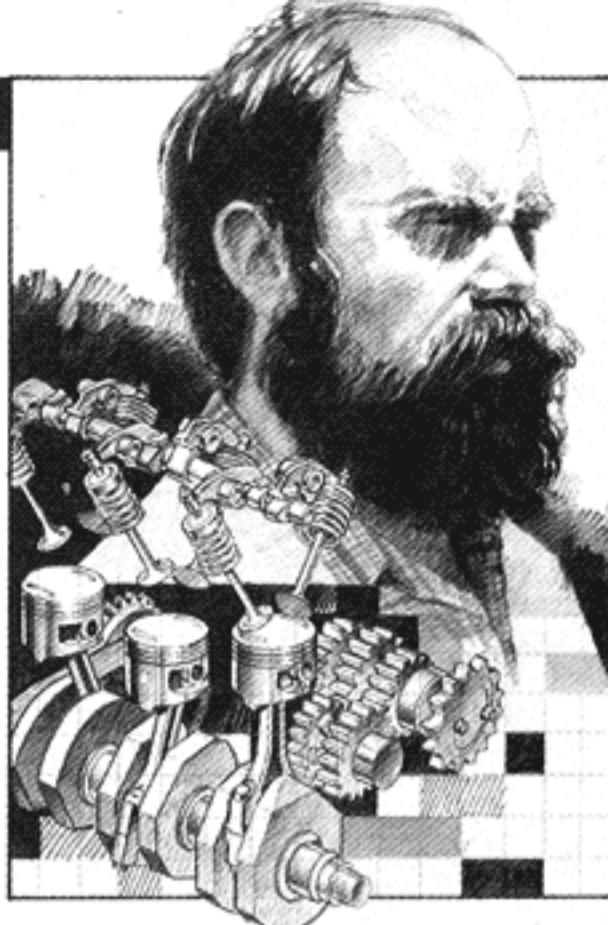
□ You've finished assembling your cylinder head and have slid it down over its studs to rest on a fresh gasket and the deck of your cylinder. You spin on the nuts with your fingers, then lightly seat each one with a short-handled ratchet. Now, ready to start tightening, you reach for the torque wrench. Have you ever thought about what is actually going on here? What is happening as you work the wrench?

As you tighten the nut on a stud, the nut's rotation tries to pull the stud up through the cylinder head, even long after the gasket has fully compressed. How can the turning nut pull more and more stud up through that hole? Because it is *stretching* the stud elastically, like a spring. And bolts and studs are exactly that—tension springs holding parts together. The studs and nuts simply provide a convenient way to apply that tension.

It takes a certain amount of pressure to ensure a head gasket won't blow, and it takes a certain amount of pressure to ensure a footpeg won't vibrate off. Therefore the main thing to remember when tightening bolts is how much *tension* you are putting into them; tension holds machines together.

The amount a material is stretched has a direct relationship to the tension resulting from that stretch. This relationship is expressed as a sort of "spring constant" for the material, called Young's Modulus of Elasticity. For steels, this modulus or spring constant has a value of approximately thirty million, and it doesn't vary much with alloy composition or heat treatment. Young's Modulus has nothing to do with the force required to break or permanently stretch a material—it only tells us how much force is required to stretch it a given amount.

When you tighten a bolt normally, then release it, it has the same length both before and after use—it has stretched, but the stretch has snapped back when the tension was released. If you deliberately tighten a bolt until you feel that dreadful loosening of the wrench in your hand, you will find, when the bolt is removed and remeasured, that it has permanently stretched. Look closely and you'll see that some part of the bolt has "necked-down" to a smaller cross-section. This is why the wrench loosened—the minimum cross-section had too little metal to resist your torque. The *strength* of a fastener is just a measure of how hard we have to pull on it before it stretches



permanently. Strength is therefore a measure of how far up the material's *elastic range* extends—how much tension we can get out of it before it begins to neck down or actually break. The *rigidity* of the material is its spring constant while still in its elastic range. *Strength* is the outer limit of the material's elastic behavior.

Obviously, if we tighten a fastener enough to drive it past its elastic range, it starts to yield, necking-down and losing cross-section, and actually *losing* tension. This is why fastener tightening torques are serious business, and not just a challenge to graduates of Charles Atlas courses. Recommended tightening torques are determined to let you use most of the bolt's strength but leave a safe margin before permanent stretch begins.

How can you know how much tension you are putting on a bolt as you tighten it? Sometimes you can measure it directly. For many engines, the manual calls out a micrometer method for tensioning con-rod bolts: measure bolt length before assembly, then install and torque until the bolt stretches a certain number of thousandths of an inch. Simple and accurate. You can't, however, use this lovely method when one end of the fastener is threaded deep into your engine cases. In that case you must rely on a torque wrench—a most imperfect method. What does a torque wrench measure? It measures the force required to stretch the bolt or stud *plus* the friction in the threads and against the washer. How much is friction, how much is stretch? There is no way to know exactly, but industry assumes a "standard" amount of friction and tries to standardize conditions when fasteners are torqued. This means new, fresh parts, free of rust, corrosion and grit, and it usually means with lightly oiled

threads. Under these standard conditions, the recommended installation torque generally produces adequate tension to keep the assembly together very nicely.

In our real world of privately owned machinery, nuts and bolts have usually been assembled at least once before (at the factory). This means that the threads of nuts will be deformed slightly, because they are designed to do just that on assembly. Nuts are purposely made softer to accommodate high spots in the threads of the harder bolts and studs that would otherwise lead to stress concentrations. After such deformation, nuts give more friction than before. Real-world rust also alters their friction, as do grit and lack of lubrication.

How can you do it right? How can you guard against assembly failures? Put back some of the factory's standardization. In heavily loaded, crucial areas like con-rod bolts or head nuts, use new fasteners every time you build. Make sure the threads are clean and apply a drop of oil before tightening. In less critical applications, at least have a look at each fastener as you build, and reject those obviously deformed or those which won't run onto their threads by hand. Be sure to clean and oil the parts.

Don't let the torque-wrench get in the way of completing the work, but do use it on crucial parts like case studs, con-rod bolts, and head bolts or nuts. Also when you are just beginning to learn about mechanics, let the torque wrench teach your hand what reasonable force feels like for the various sizes of fasteners.

What about the various grades of fasteners? You can get bolts with yield strengths all the way from the 60,000 psi of hardware store bolts to the 240,000 psi of aerospace materials. What to use? The rule is "special fasteners for special applications." Are you turbocharging your engine? Then use the best cylinder studs you can find, torqued to a tension that just produces a reliable seal. Are you planning to rev your little gem 2000 rpm past redline? Good, *fresh* rod bolts are an absolute necessity.

Super-strength fasteners can become a mania, but remember that a grade-8 bolt and a grade-12, both torqued to the same value, yield exactly the same tension. High-strength bolts are necessary only when high tension is necessary. ■