PERFORMANCE PUSHROD TECHNOLOGY

Evolving designs improve valvetrain stability

BY **MIKE MAVRIGIAN**

Example of a Manton pushrod with tapered ends. The hardened ball end (black tip) engages the rocker. The heavier end engages the lifter. The tapers provide added clearance for high-lift applications.

The pushrod in OHV systems is often the weak link in a high-revving, high-lift and high spring pressure application. The entire valvetrain is subjected to potential harmonics and valve spring frequencies. In an OHV engine, pushrods play a major role with regard to valve spring dynamics, valve stability and valve bounce.

Pushrod stiffness is a critical issue. When pushrods flex under extreme springs loads and high lift conditions, the flexing can interrupt the transition of dynamic force between the lifter and valve, to the point where it can result in erratic and somewhat late camshaft timing. The quick transition from a no-load (at the base circle lash setting) to peak stress approaching full lift, where spring pressures are highest, with more intense loads at the exhaust pushrod as higher cylinder pressure must be overcome. While conventional thinking routinely dictates that we should attempt to reduce valvetrain component weight, heavier (larger diameter) steel pushrods are favored by many, where the tradeoff of additional weight vs strength and rigidity makes sense in order to reduce the potential of flex. Pushrod flex induces frequencies that are transmitted through the valvetrain. This results in instability which can cause the rocker tip to oscillate, dancing around the rocker cup or adjuster ball instead of maintaining a consistent center contact, in addition to cam timing fluctuation.

Pushrod taper (one end or both) allows use of a thicker center or lower mass for added strength along with providing clearance (where needed) for rocker arm, and where required, for lifter clearance and pushrod-to-head as well. Elgin's one-piece tapered-end pushrods (referred to as swedged ends) feature a short taper at each end, providing additional rocker arm and lifter clearance while maintaining a straight profile along the rod body. Increases in intake runner volume, common in aftermarket cylinder heads, often create pushrod clearance issues, prompting the need for tapered pushrods where diameter is decreased in the upper body but increased in the lower section in order to increase stability at the lifter end. This allows the manufacture to maintain a larger body

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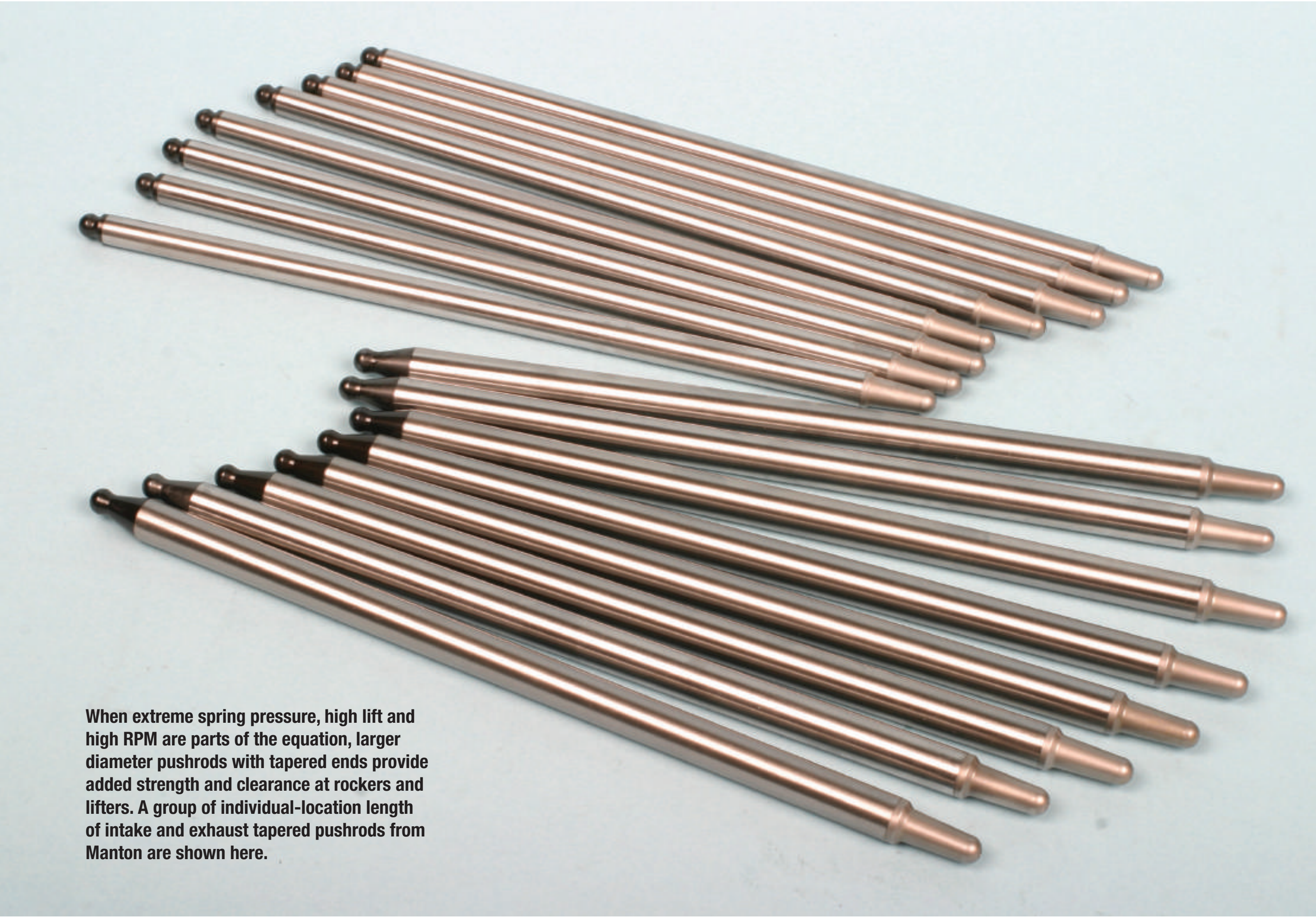

When extreme spring pressure, high lift and high RPM are parts of the equation, larger diameter pushrods with tapered ends provide added strength and clearance at rockers and lifters. A group of individual-location length of intake and exhaust tapered pushrods from Manton are shown here.

diameter while accommodating these clearance issues. If a pushrod features a single taper, the tapered end mates to the rocker, where the heavier-mass end is directed to the lifter, where impact and dynamic loads are higher. In certain applications, a beefy pushrod in the 1/2" – 9/16" diameter range may feature a "clearance notch," (as noted by Trend), reducing body diameter about halfway down the body to reduce rub where the pushrod runs through the cylinder head, leaving maximum thickness in the area that doesn't run through the head. Flex-reducing thickness becomes more critical as pushrod length increases, as in Top Fuel, where pushrods tend to be in the 11 to 12" range.

A fairly recent innovation is the adjustable pushrod, which allows precise length tuning for non-adjustable rocker arm systems. COMP Cams' XD-A Shim Adjustable pushrods are an example of this approach. As explained by Comp: The Patent Pending new pushrod system design incorporates a smaller top section that slides 2" deep inside a larger bottom section with one or two shims captured in between the sections to accurately set lash or preload. This opens up a simple way to accurately set lash or preload while using far more durable and lower mass non-adjustable style rocker arm assemblies. The adjuster and nut on shaft-mounted rockers weigh approximately 20 grams. Once you add the extra material for threads and support, the system mass may grow to about grams. This is basically the difference in mass of a Ti vs Steel valve hanging off the back side of the rocker arm, and all of this added mass does nothing to improve the rocker stiffness. In contrast, the mass added when moving the adjustment into COMP Cams' new XD-A pushrod almost doubles its stiffness in bending by shortening and supporting the smaller OD top section. This is a major improvement as pushrod bending can be the weakest factor in valvetrain stability (as demonstrated by the prevalence of 7/16", ½" and even 9/16" OD, thick wall pushrods in professional racing).

In LS applications the 7/16" OD bottom section and 5/16 x 0.105" wall bottom section create an assembly that has 90% greater stiffness than a standard 5/16" single piece design, while the 7/16" bottom section fits easily though the 12mm pushrod clearance holes in factory cylinder heads. The bottom section length is sized to remain under the cylinder head and gasket at any lift during operation, resulting in the same running clearance as any 5/16" design.

The XD-A Pushrod system has been proven in solid roller LS applications though Spintron test to 9000+ RPM and aggressive dyno testing. Lash setting stayed extremely consistent throughout testing and pushrod lengths remained the same before versus after operation. With fresh cylinder heads, you may consider setting the lash about 0.001" to 0.002"

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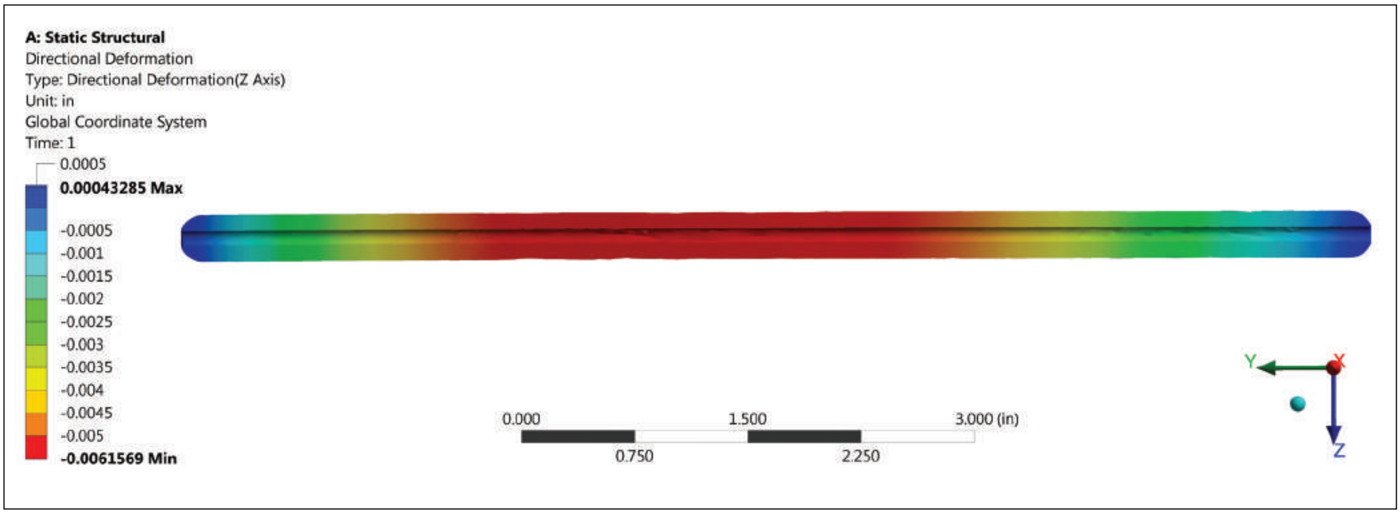
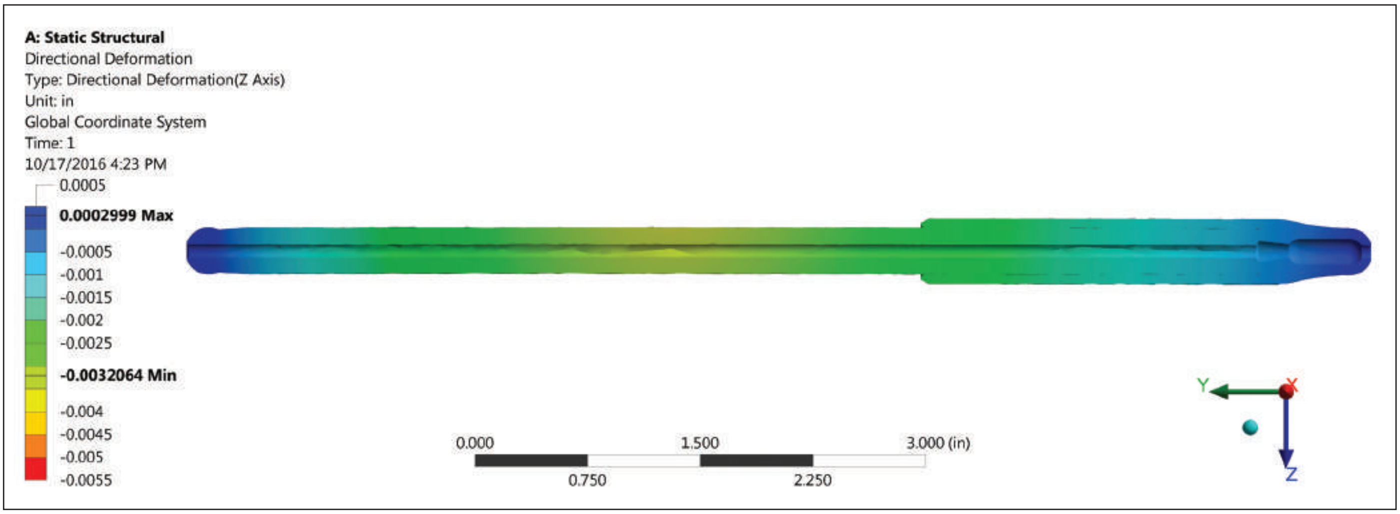


ABOVE: A straight pushrod tends to exhibit directional deformation at the center area, as shown I this 5/16" example (with highest deflection in red).
BELOW: Adding mass to the lifter end, as shown in this example of COMP's adjustable pushrods, decreases directional deformation substantially.
(Illustrations courtesy COMP Cams)



looser than normal just to allow for the valves seats to settle.

The new XD-A shim adjustable pushrod system incorporates a new patent pending system to give the accuracy and durability of direct OHC pill under bucket style adjustments inside a slide-together multi-piece pushrod design. Simply remove the pushrod and change shims to set the required lash or preload. Shims are currently available in 0.004" increments and can easily be sanded in a figure 8 pattern for extremely fine adjustment.

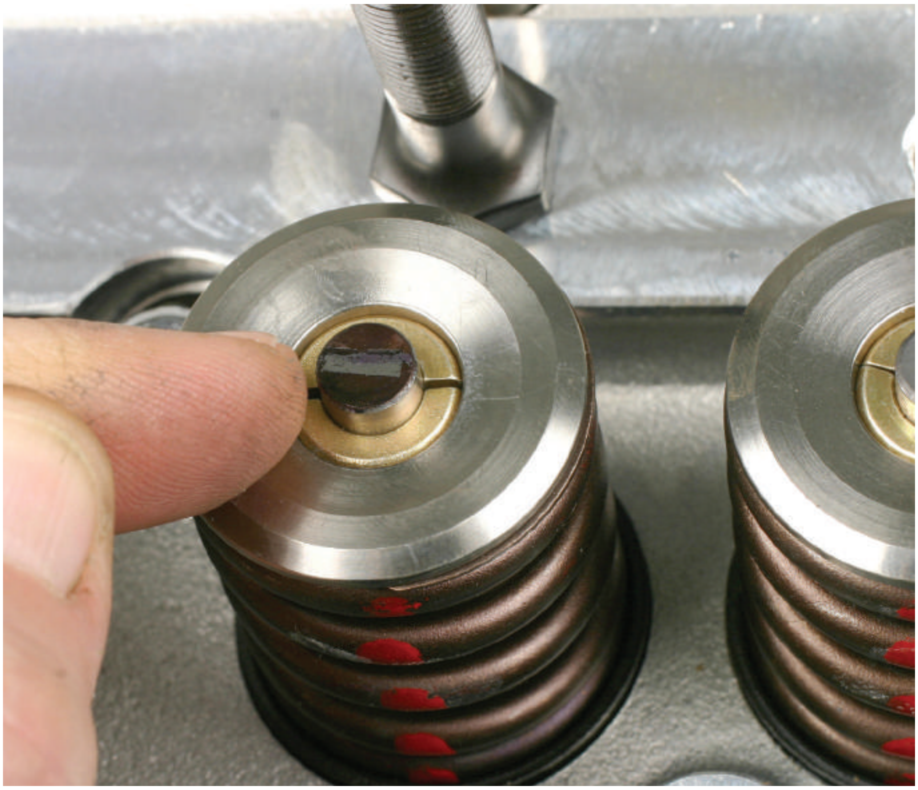
Applications include any pushrod operated engine, and especially relevant in GM Gen III through Gen V small block V8's, including LS1, LS3, LS7 and new LT engines, with their low mass rocker arms and light valvetrain. One set of Pushrods can be adjusted over a 0.232" range in 0.004" increments using one of two shims, and top sections are available in 0.200" increments for course adjustment. According to COMP, the XD-A pushrods provide a 90% Increase in bending stiffness comparing the 5/16-7/16 XD-A to a standard 5/16 x 0.080" wall pushrod.

A discussion of pushrod ball tips is in order. While 180-degree ball ends have been the norm, with a move to higher valve lift, interference at the rocker arm may occur. A more generous tip radius (210 degree offered by Trend, for example) can provide additional operational clearance at the rocker pushrod cup under more severe rocker arm angle. The extended tip radius provides a bit of under-ball contact to accommodate severe arm angle during full-lift transition. For rockers that feature adjustable ball-tipped studs, a relatively shallow cup radius at the upper pushrod tip can aid in providing additional high-lift clearance. Some builders prefer to convert to a ball-cup at the rocker tip (obviously requiring adjustable ball-stud rockers) in order to retain more oil at the pushrod upper tip during high engine speeds. Cup style pushrods can be formed into the pushrod, or as inserts, sometimes with the insert featuring bronze or a copper alloy for extreme RPM levels. Adjuster balls always need to be harder than the cup material. Cup-equipped pushrods often feature a somewhat shallow radius to benefit rocker arm clearance. The range of available pushrod tip materials, profiles and radii is extensive to suit a variety of applications, including both oil-through and solid designs for street through all types of racing applications. For example, according to Trend, applications for Top Fuel and Funny

Car may feature solid tool-steel with no oil passage to the ball stud through the pushrod body, a 3/8" ball at the lifter end and a 3/8" cup at the rocker end, in diameters of 716" or ½", hardened to 54 to 56 Rockwell C.

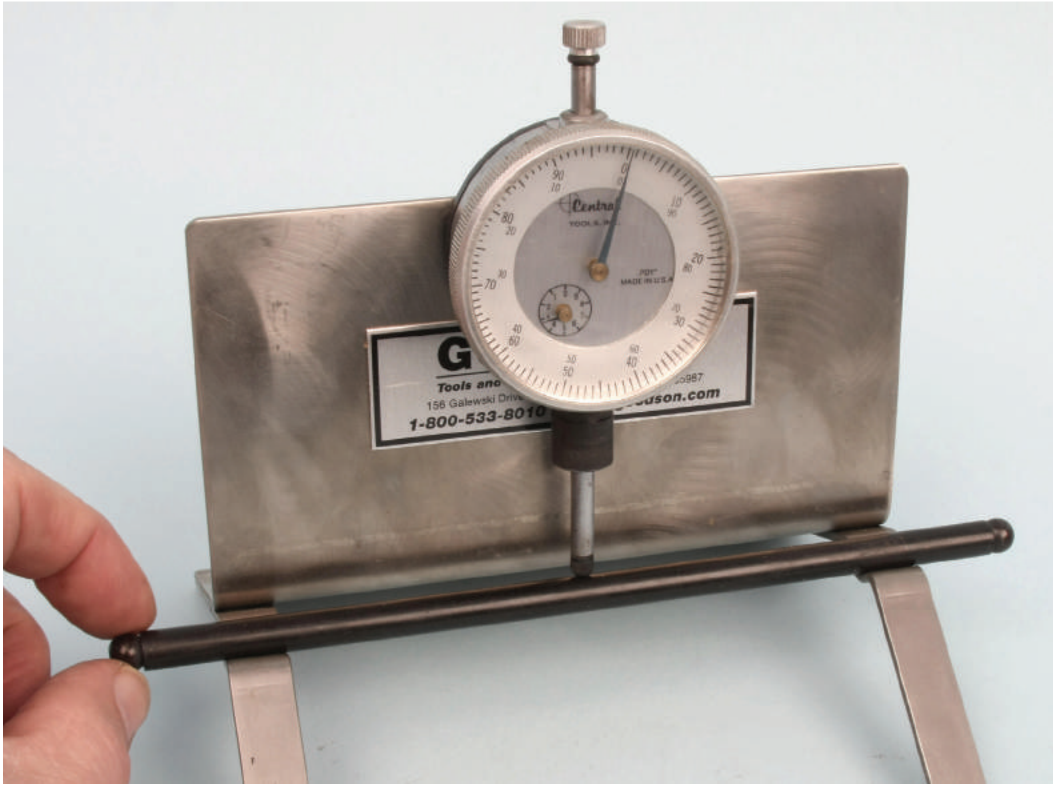
Pushrod diameters and wall thickness obviously play a major role in stiffness and resistance to deflection. However, body diameter is much more crucial as compared to wall thickness. Regardless of the application, the rule of thumb is to run as large a diameter as possible, given the clearance confines. While 5/16" diameter may be suitable for a mild street application, as factors such as compression, RPM and spring pressures are increased, the need increases for greater pushrod diameter. Diameters ranges include 5/16", 3/8", 7/16", ½", 9/16" and 5/8" and in some extreme cases, even ¾".

As noted earlier, it's preferable to run the largest diameter pushrod that the engine will accommodate. This helps to reduce deflection and increase valvetrain stability. That doesn't mean that you necessarily should move from a stock 5/16" diameter to a 7/16" diameter. Today's pushrods (by the quality manufacturers) are comprised of



Correct pushrod length is key in obtaining a center contact sweep of a roller lifter to the valve.

Rocker arm adjusters are available in a variety of cup and ball configurations in terms of diameter and radius. Adjusters should always be harder than the pushrod rocker tip. (courtesy Trend)



Routinely checking for pushrod straightness should be performed as part and parcel of any engine inspection during teardowns and/or between-race checks. While the pushrod may deflect during operation, a static runout check will help. If you find more than 0.002 – 0.003" runout at the center during a static check, chances are the pushrod has been deflecting more than this during loaded operation. Some may debate the runout limit, but If a static check reveals more than 0.003" runout, it should be replaced. Some makers provide straightening service, but replacement is recommended.

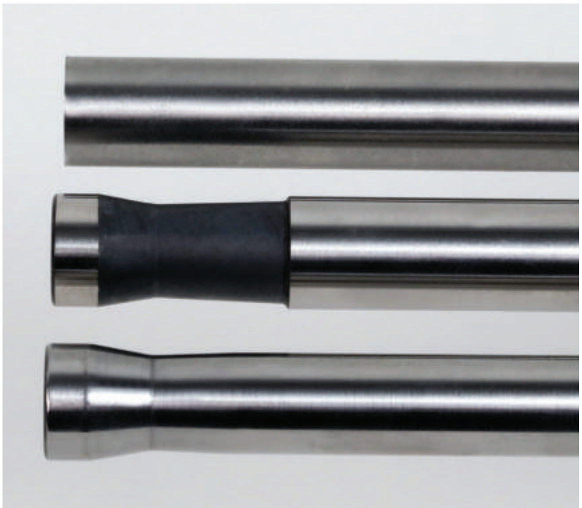
advanced materials and are available in wall thicknesses to enhance the goal of stability. I'm simply saying that if a 3/8" diameter pushrod will easily fit, this is preferable to a 5/16", etc. Don't be overly concerned about pushrod weight, since the pushrod is on the "slower" side of the valvetrain. When it comes to weight savings, it's more important to consider the faster side of the system (rockers and valves).

As noted several times in this article, pushrods are exposed to forces that try to make them deflect (bend), which generates unwanted valvetrain harmonics. This is because of the eccentric loading that results from the angular load that is created as the rocker arm moves through its arc. Materials and design aside, the longer the pushrod, the more beneficial it is to use a larger pushrod diameter (the theory being that a larger diameter tube will deflect less than a smaller diameter tube).

It's best to consult with the pushrod maker when ordering custom pushrods. If we're speaking in very general terms,

1: This Trend NZ series pushrod uses a bronze insert that is pressed into the end of the 4130 chrome-moly pushrod. This allows the pushrod shank to be made from one metal, while a softer metal ensures there will be no galling at the rocker arm end.
2: This H-series pushrod is machined from a solid billet of H-13 tool steel, making it exceptionally strong.
3: V-40 cup pushrods feature self-lubricating tool steel tips. Designed for high-RPM, high-power valvetrains, combining the strengths of H13 with the self-lubricating properties of tool steel.
4: This is actually a Top Fuel-style pushrod which is made from H13 tol steel. This version has a formed cup-style end to maximize clearance. (courtesy Trend)

In addition to welded-ball-end style, Elgin's one-piece pushrods feature swedged (taper) ends and 220-degree radius to accommodate high lift applications. (courtesy Elgin)



Shown here is a Top Fuel pushrod which begins life as a one-piece H13 billet. The billet is then machined into the final shape. Building the pushrod out of a single piece of material maximizes strength. (courtesy Trend)

Many performance pushrods are laser etched to readily identify length and wall thickness.

0.080" or so wall thickness should be adequate for most moderate high performance street engines. However, when building a race-only engine that will experience high lift and high rpm use, moving up to 0.120" or thicker is prudent. Again, don't be concerned with pushrod weight. The pushrod is on the slower end of the valvetrain. Trying to save weight by going to a smaller diameter and/or thinner wall isn't going to gain anything, and may result in entering an excessive pushrod deflection range. If a pushrod flexes, the resulting change in pushrod length and angle of contact between the pushrod and lifter can pound and attempt to cock the lifter during travel, which can lead to lifter failure.

Where applicable, by moving to a single taper pushrod (thickest area close to the lifter), you'll reduce deflection even more. This is of more benefit when using roller lifters, high ratio rocker arms, and multiple valve springs at high rpm.

As you might expect, pushrod materials play a major role in compression strength and resistance to flexing. Mild steel 1020 may be fine for a mild street application (57,000 tensile range), but the majority of performance pushrods are made from 4130 steel alloy, which provides almost twice the tensile strength of mild steel at approx.. 97,000. For the most severe applications, H13 billet steel provides about three times the tensile strength of 4130 at around 289,000, making H13 suitable for extreme use in Top Fuel/Funny Car drag applications.

All pushrod manufacturers employ (often proprietary) heat treating to achieve the desired molecular uniformity, tensile strength and durability. Elgin, for example, offers their "Black Ice" cryogenic treatment in their Pro Stock line of 5/16", 3/8", 11/32" and 7/16" pushrods in order to maximize material and geometric stability and uniformity and wear resistance.

Citing Elgin Pro Stock rods as but one example, these are made from seamless 4130 tubing, with their 5/16" pushrods providing .109" wall thickness, and 3/8" rods with .137" wall thickness. Proprietary heat treatment is applied for extreme wear resistance, Increased Stiffness and column strength. Requirements, far exceeding OE requirements. Ends are fully hard turned ends (after heat treat) to ensure accuracy. A healthy 220 degree of travel on radius ends accommodate high lift applications. As with most aftermarket performance pushrods, application lengths are available in .050" increments.■

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