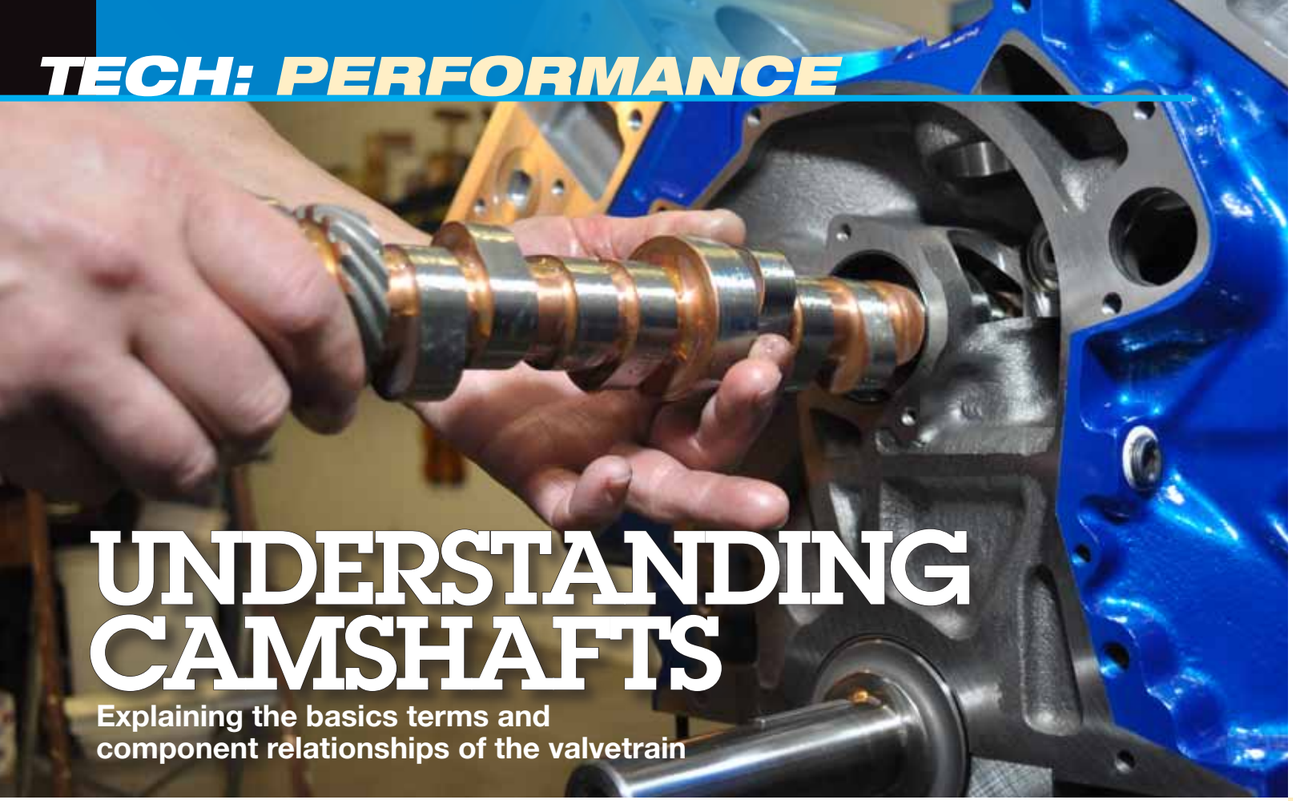


UNDERSTANDING CAMSHAFTS

Explaining the basics terms and component relationships of the valvetrain

Words and photography by Sam Logan

Intelligently analyzed and carefully selected, performance camshafts can have a profound impact on the power output of an engine. But the specifications listed on the outside of a camshaft box are often bewildering: What do they mean, and how can you take advantage of them? Choosing the proper camshaft can be a daunting task, as the right combination of lift, duration and other factors will determine how an engine performs. Further, these values have to be matched to suit the particular engine combination being used.

Perhaps the first rule of cam selection to bear in mind is, bigger is not always better. This is where many performance enthusiasts go wrong, and it's probably the primary reason shoppers should consult with the camshaft manufacturer's tech help lines before placing an order. As Jeff Sams of Lunati said, "We get numerous calls every day with regard to choosing the correct camshaft profile for performance engines. And that's what we're here for."

Jeff was among the experts we consulted with to compile this primer on camshaft terminology. Camshaft design is a science unto itself, but with even a basic understanding of the terms involved and how the various specifications affect engine performance, you can make a more informed selection.

Valve Lift

We'll start with valve lift, which is usually the first term used in camshaft discussions. Fortunately, it's a fairly straightforward concept. Valve lift is an expression of the maximum distance the valve travels off of its seat, as the lifter, or tappet, reaches the nose of the camshaft lobe.

Camshaft makers use valve lift to induce as much airflow through the engine as possible. As an example, if the valve lift is listed as .650-inch on both the intake and exhaust, this means the incoming charge enters the combustion chamber through a maximum opening around the intake valve of .650-inch and the exhausted gases exit through a similar maximum valve opening as they escape into the exhaust port.

Valve lift involves considerations beyond engine breathing, as race engine builder Chuck Lawrence of Jon Kaase Racing Engines suggests. "Knowing the amount of valve lift conveys many important spring requirements. The valve lift figure, for example, determines how tall the valve spring needs to be to enable it to open fully without becoming coil bound (a condition in which the individual coils of the spring actually contact one another)."

"It is also important," continues Chuck, "to ensure the bottom of the spring retainer does not make contact with the valve stem seal or the valve guide. Further, the key to selecting optimum spring pressures is to find the lightest pressure that will close the valve, keep it closed, and not allow it to 'chatter' on the valve seat." This is why it is advisable to consider a set of valve springs that has been matched to the cam being selected, or to consult with the cam manufacturer for spring recommendations.

Lobe Lift

Valve lift is a function of lobe lift and rocker ratio; that is, lobe lift is multiplied by the ratio of the rocker arm to yield the total amount of lift realized at the valve. However, lobe lift itself is simply a measurement of the lobe's overall dimension from the heel to the toe minus the base circle dimension. That measurement, multiplied by the rocker arm ratio, generates the total valve lift figure.

Consider a lobe lift dimension of .312-inch and multiply it by 1.7 (a common performance rocker-arm ratio) and the resulting valve lift will be .531-inch. Rocker ratios vary from engine to engine, and even within engine families. For example, the small-block Chevy has traditionally used 1.5:1 rocker arms, while Ford small-blocks most often use 1.6:1; some high-performance Ford small-blocks have used 1.7:1 and the LS-series of V-8s from General Motors have used a range of rocker ratios up to 1.8:1.

Changing the ratio will affect the overall valve lift, and, in some cases, can cause clearance issues between the valve and piston. In addition, the greater the lobe lifts, the greater distance the tappet travels within its bore and, as a result, the more it is affected by wear and tear. Often, engine builders will select a camshaft with moderate lobe lift and increase the rocker ratio to gain extra valve lift.

Advertised Duration

Camshaft duration is a measure of the period of valve opening, expressed in degrees of crankshaft rotation. There are several ways of taking this measurement, and these variations are the reason that such values are sometimes listed as "advertised duration" and other times displayed as "duration @ .050."

Although it is no longer commonly used as a reference in the industry, advertised duration merely indicates a measurement of lobe duration from valve seat-to-seat. When thought of in those terms, it can have a varied effect in exactly how the measurement is taken. For example, Lunati measures its advertised duration of hydraulic camshafts at .006-inch of valve lift off the seat, while the advertised duration of a solid-lifter camshaft is measured at .020-inch. This does not exactly give you an ability to compare one camshaft to another. Complicating the issue further is the fact that other cam manufacturers, as well as the automakers, have used alternate lift points to bracket duration figures.

Duration @ .050

In contrast to advertised duration, the term "duration at .050" (tappet lift) has become very common, as it was established as a proposed industry standard, offering a solution to the varied means of measuring duration being employed by the different camshaft vendors and auto manufacturers. As such, it is now used by engine builders and manufacturers as a way to more accurately compare camshafts.

The technique is fairly simple—the lobe's duration is measured in degrees of crankshaft rotation between the point where the lifter has risen .050-inch from the base circle to the point where the lifter is .050-inch from returning to the base circle.

Jeff Sams of Lunati explains in more detail how this is measured with the use of a degree wheel and dial gauge indicator on the tappet. "First, rotate the engine clockwise until the tappet is raised to .050-inch on the dial gauge indicator and mark your degree wheel. Holding slight tension on your camshaft to eliminate slack in the chain, continue to rotate the engine in the normal rotation until the lifter rises all the way up and then all the way down to .050-inch (from valve closed position). Next, read the number on the degree wheel and add up the total amount of degrees of rotation, which will represent your duration at .050-inch"

Center Line

Although each camshaft lobe has a theoretical centerline running through the camshaft's axis to the point of peak lift, the

1

Freshly machined camshafts can sometimes resemble pieces of art, but despite appearances, there is nothing random about the placement and dimensions of their lobes and journals. Each lobe is the product of extensive research, testing and development, resulting in profiles that must be accurate to within thousandths of an inch.

3

The etchings on Lunati camshafts typically denote the product line of cam (in this case, Voodoo); the part number (60512), which determines the grind profile; the day the cam was manufactured; and the lobe separation angle (113 degrees).

2

The specifications of a typical performance camshaft are often listed on the box, as seen here, or on a card inside. While these specs and the terminology that accompanies them can be confusing to the average enthusiast who hasn't been involved with racing or engine building, a little basic education can help to demystify the process of selecting the right camshaft for your application.

4

The term "degreeing" indicates camshaft position in terms of crankshaft rotation. Here, the engine builder is adjusting his intake center line. The same tools and a similar process are used to check duration at .050-inch.

term “center line,” as found in the cam’s specs, refers to the point of peak lift of a camshaft lobe in relation to top dead center (TDC) of the piston as measured in crankshaft degrees. Jeff tells us, “The center line of a camshaft is based on the timing events best suited for a given application.”

Mark McKeown of MME Racing says, “Advancing the cam’s center line moves the torque curve lower or sooner in the RPM range. Retarding it moves the torque curve higher or later in the RPM range. It is often misunderstood that advancing makes more torque and retarding makes more horsepower. In reality, peak torque is rarely affected; it just occurs at a lower or higher RPM. But when torque occurs at higher RPM, it does create a horsepower gain.”

Valve Lash

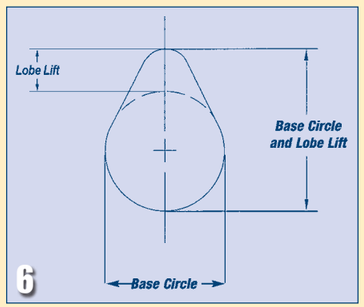
Valve lash is the mechanical clearance in valvetrains with solid flat tappets or solid roller tappets. It is measured between the valve stem tip and the underside of the rocker arm when the valve is closed, and usually while the engine is at operating temperature.

Jeff said, “Valve lash requirements can change depending on the design of the lobe profile. The proper amount of lash ensures the valve closes completely and also prevents damage to the valvetrain when the valve opens. Lash settings can be adjusted a certain amount and used to fine-tune the engine’s performance. Tighter lash opens the valve sooner and closes it later, while looser lash does the opposite. When used to fine-tune, lash has the same effect as a bigger or smaller camshaft. It’s important to note, though, that the cam manufacturer should be consulted before varying from the recommended specification.”

Valve lash is meant to be adjusted when the lifter is resting on the base circle of the cam lobe; an easy way to work with this is to turn the engine until the exhaust valve of a particular cylinder begins to just crack open, and then adjust the intake rocker on the same cylinder. Rotate the engine in its normal rotation until the intake valve is almost closed and then proceed to adjust the exhaust rocker.

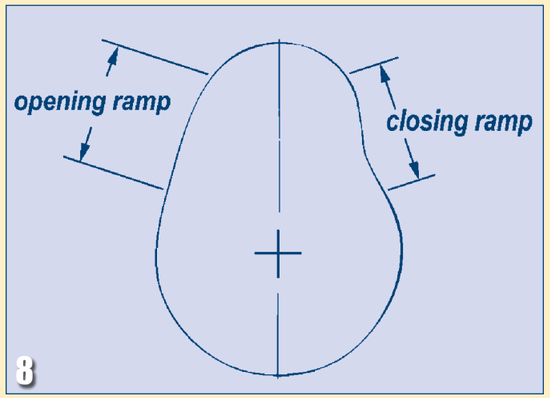
Like most other things, knowledge is power, and a little understanding of camshaft terminology can go a long way toward assisting you in your search for improved performance. Check the sidebar for addition terminology, and don’t hesitate to consult with the technical experts at the various camshaft companies.

Valve lash measurements on race engines with solid flat tappets or solid roller tappets are often used as a tuning aid—they’re increased or decreased to suit the particular model engine.

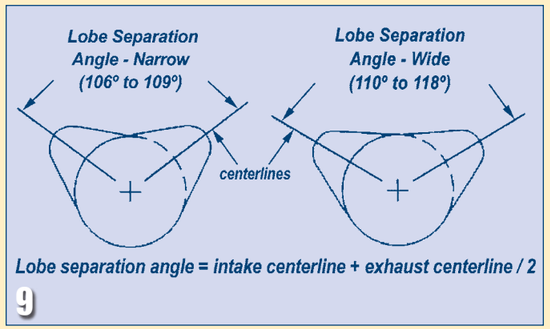


Lobe lift is determined by subtracting the base circle dimension from the figure measured at the peak of the lobe.

Rocker arm ratios multiply the effect of camshaft lobe lift to yield valve lift. The rocker’s ratio is the distance from the center of its pivot point to its tip (where it exerts force on the valve stem) divided by the distance from its center of pivot point to the point where the pushrod makes contact. In the case of an LS grind, a cam lobe lift of .312-inch, when multiplied by the stock LS rocker ratio of 1.7:1, would theoretically generate a valve lift of .531-inch.



The portions of the cam lobe leading from the base circle to peak lift and then back to the base circle are referred to as the ramps; the term “ramp angle” is used to describe the specific dimensions of the ramps used with a particular lobe profile. An asymmetrical ramp is shown.



Each camshaft lobe has a center line that runs between the peak of the lobe and the camshaft’s axis; the dimension that exists between the centerline of the intake lobe and the exhaust lobe is expressed as lobe separation angle (LSA). Narrower LSA profiles favor power production in the upper RPM range, while wider LSA promotes smooth idle and low-end torque production.

Other Camshaft Terms

- **Lobe separation angle (LSA)** is formed between the center line of the intake lobe and the center line of the exhaust lobe, and provides an indication of the amount of valve overlap.
- **Lobe ramp** refers to the opening and closing sections of the camshaft lobe—the area between the base circle and the lobe peak. The specific dimensions of these ramps are often referred to in terms of “ramp angle;” the more aggressive the ramp angle, the faster the valve opens and closes.
- **Single-/dual-pattern camshafts** relate to intake and exhaust profiles that are either the same or not the same; single-pattern cams use the same profile on both the intake and the exhaust, while dual-pattern profiles differ between the two.
- **Symmetrical or asymmetrical camshaft lobes:** A symmetrical lobe has the same opening and closing ramp profile; modern technology has led to the development of asymmetrical lobes, which use varying opening and closing ramps to open the valve more rapidly while closing it more gently to prevent valve chatter.

The complexity of modern camshaft lobe profiles means that measuring their dimensions is difficult for the average end user. However, a micrometer can be used to provide an accurate lobe lift figure; here, an inspector checks the overall dimension of a lobe during the manufacturing process.

Camshaft manufacturers use equipment that can “read” a camshaft’s lobes to provide all of the critical dimensions as part of the inspection process. This apparatus has been programmed with the cam profiles it will be checking, which it does by running the ball along the lobes, then comparing its findings with the design data. Its duties include measurements of taper, base circle, base circle run-out, toe-to-heel and lobe separation angles.

Sources:

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662-892-1500 • www.lunatipower.com
MME Racing
301-932-9292 • www.MMERacing.com
Jon Kaase Racing Engines
770-307-0241 • www.JonKaaseRacingEngines.com