Surface Qualities for Performance Engines

BY **JOHN GOODMAN**

The best way to approach the subject of optimal cylinder wall surface is to understand some of the basics:

1. We attempt to seal compression and suction with piston rings
2. Ring, piston and cylinder wall design and material play a big role in how and what type of surface you generate
3. The conditions under which you race (dirt, salt, sand, etc.).
4. The type of working fluid(s) you use (fuel, gasoline, gas, etc.)
5. Metrology

First, when we discuss the condition of a race engine we reference a compression ratio or leak down value. In each case, an attempt is made to find the culprit that robs us of expensive and valuable compression. But, keep in mind; we only compress what air/fuel we take into the cylinder during filling. The age-old example of calling our normally aspirated gas and diesel burning engines air pumps is not far from the truth. If rings fail to seal under suction (filling), we will not draw the maximum air/fuel volume into the cylinder and performance suffers. This holds true for positive displacement induction systems as well. If the rings won't seal on suction, they certainly will not seal when you kick a few additional atmospheres into each cylinder.

Second, the combinations of ring, piston and cylinder wall material is staggering. You literally have a choice for any contingency. In our world, cast iron cylinder walls, hypereutectic, hypoeutectic and forged aluminum alloy pistons are commonly used for racing. Hypoeutectic not so much but I still see them where rules dictate. Four common racing piston rings are: ductile and grey cast iron, tool steel and stainless steel. Throw in nitride, chrome and both plasma moly and moly-filled coatings and you get the picture. No single surface will work for them all.

While on the subject of rings, it should be noted that many ring face designs exist. There is the ubiquitous beveled face, radius (barrel) face and straight face. In all cases, pre-lapped and/or double lapped ring faces are very important to qualify. Most quality ring packs come with lapped faces so this should not be a worry.

Thirdly, certain ring and coating materials lend themselves to specific track surfaces. At Bonneville and El Mirage, where caustic and abrasive track elements can find their way into the engine, it may be better to consider nitride or hard chrome face rings. These harder surfaces resist wear and hold sliding seal properties longer. Contrary to popular opinion, these rings take the same surface finish as other common racing ring packs so long as top ring faces are pre-lapped for a light tight seal in a straight, round cylinder bore.

Moly-coated/filled rings are used for high ring face conformability and are best suited where cleaner air exists. The plasma moly rings are more forgiving and do handle heat well. It is no wonder why these are the #1 choice among many engine builders. However, if the surface finish is not right, these rings can degrade rapidly and may not deliver optimal performance over the period of a week of racing.

Fourth, the working fluid and I don't have to tell you how many choices you have here. If we have learned anything it is there is nothing simple about gasoline. What should be considered is how your chosen fluid works in the engine. Does it have high detergency? Will it cause unusual tuning problems? Is it compatible with all engine components it comes in contact with? Indirectly, answers to these questions play a part in which ring pack you select and in turn, what surface finish you put on the cylinder wall.

Lastly, metrology and here is where the wheels fall off. For most of us, a single surface parameter is used (if used at all) to determine surface quality. That parameter is Ra. Ra or Rms is nothing more than an arithmetic average (or root mean square) of all peaks and valleys recorded in a single sample length from a surface measuring tool called a profileometer. Ra attempts to tell you how rough the surface is. Too rough and the surface will destroy rings. Too smooth and the rings may not seat. Ra alone is of little practical use and no more valuable than rubbing a penny across the cylinder wall to determine surface roughness and/or quality. At this point, things get interesting.

OK, Ra is not a good indicator of actual surface roughness so what is? As it turns out, an ISO standard of Rk surface measurement parameters fills the bill nicely. Rk attempts to segregate peaks, core roughness and valleys. So, for the first time, you can see how rough the bearing area of a surface is without much mathematical interference from valleys (Rvk). All together, they identify surfaces both good and bad. I won't get into every parameter of Rk but we will look at Rpk (peaks), Rk (core roughness. This is the area of surface that will ultimately bear load.), Rvk (valleys) and Vo (potential volume of oil retained in the surface). Armed with values for these four measurements, you can come very close to understanding the most critical elements of a honed cylinder wall surface.

Most of us have heard about plateau honing. Essentially, this surface is purposely honed to greatly reduce peaks while leaving the deeper valleys for oil retention. If done correctly, the peaks are eliminated and core roughness is prepared for maximum load bearing capability. This type of surface demands pre-lapped ring faces because there are no peaks left with which to carry out an uncontrolled ring lapping task. Now think about what was just said. If you leave a peaky surface and this surface is required to finish lapping ring faces (hey, we need that light tight seal if we are to maximize our compression and suction efficiencies, yes?), where do you think worn ring and cylinder wall material goes? More about that later; common sense dictates that we do not want an uncontrolled machining process (using peaks to lap ring faces) to take place in our race engines or our passenger car engines for that matter. We should strive to finish hone a cylinder wall to remove all peaks and micro burrs. What is left behind resembles a run-in engine. How is a plateau finish accomplished? Well, there is more than one way to do this but an acceptable method has you hone about .003" stock with a 80-100 grit stone, .0015" stock with a 280-320 grit stone, .0005" with a 400-600 grit stone and finish this off with a 320 grit abrasive filled nylon filament brush. An 800 grit cork bond stone can replace the brush tool if you like them better. The 80-100 grit abrasive removes the bulk of stock. It also leaves sufficiently deep valleys that you will likely not remove entirely with upstream honing operations. This is ok. The 280-320 grit abrasive prepares the core roughness of the surface and regulates the amount and valley depth.

The 400-600 grit abrasive prepares the plateau or load bearing attributes of the surface. Finally, the 320 grit brush (or 800 grit cork bond stone) removes all surface defects left behind from honing operations. Now, here is where you can get creative. You can use the 280-320 grit abrasives to alter the Rvk measurement to leave more or less valley depending on what you are trying to accomplish. If you have a diesel engine, I would build into the surface considerably more Rvk (valley) than I would for a gasoline burning engine. Cylinder pressures are much higher for diesel engines and they suffer cold start piston scuff if there is insufficient oil retention on the wall surface. Consequently, I would also want to see higher Vo (volume of oil retention) numbers coming off my profileometer. I did use this type of surface on a gasoline burner a few times. The surface looks like trash to the naked eye but boy, did that engine make power. By leaving a greater surface area of the cylinder in valley, I was able to reduce surface area available to the ring, thereby greatly reducing friction in the highest friction-producing area of the engine. Just be prepared for oil consumption. If this engine was to be used for endurance, lowering Rvk and Vo would be vital. You want all the benefits of reduced peak count but greater control of oil consumption. It does you no good to build a killer engine that consumes more oil that is required to finish a race. The Indy 500

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is such a race and the teams are not allowed to add oil once the race starts. Now you should begin to see why it is so important to select rings, pistons and cylinder wall surfaces that match the venue in which you race. One size does not fit all.

Well, as it turns out, there is another family of surfaces that is not a plateau. It is called peak hone and is further broken down into smooth peak and conventional peak. This type of surface is pretty straight forward with exception that Rvk and Vo are dramatically reduced from what is considered a normal plateau. In fact, it is quite possible to bring the Vo down so low that there is virtually no oil retention available to rings or pistons. Only a good deal of hot-run data can point you to that line where to little Vo is dangerous to the longevity of the engine. While we are talking about smooth peak surfaces, it is my opportunity to say a few derogatory remarks about polishing cylinder walls. At first blush, this would seem a good thing. But think about what you are doing.

Remember all those surface defects generated in a normal honing process? You know the ones you removed with brush and cork bond honing? Well, that defect layer is full of other unwanted debris that comes from spent abrasive crystals, unknown particles in the honing fluid, and whatever you are using to polish with. You may end up with a mirror finish but it will be one of the most destructive finishes you could have produced for your rings. Within a few rotations of the crankshaft, this unstable polished layer is removed. Particles are released from the surface and imbedded into piston skirts and ring faces. Continued running of the engine increases the damage caused by these abrasive particles until rings fail completely. If you are lucky and the engine doesn't destroy itself, all that premature wear of sliding seal components go directly into your oil supply and is pumped to every nook and cranny of the engine. Just think about all those abrasive bits in your soft bearing material, constantly wearing on crank and cam journal surfaces. It isn’t a pretty sight.

I have probably rambled on far too long to be of any benefit to you but please approach cylinder wall surface with as much respect and investigation as you do with other critical areas of the engine. IT IS NOT A BLACK ART! Surface finish is understandable, definable, measurable, controllable and easily subject to analysis. Choose wisely and you will have trouble free and almost break-in free race engines with increased reliability and performance.

One final word; No matter how careful you are in the selection of rings and preparation of cylinder bores, if you do not make straight, round bores your rings will not seal properly, you will lose power and experience copious amounts of oil consumption. Pay attention to details! Almost good is not good enough.■