Cylinder/piston Material Selection for Model Engines

Created: Jan 29, 2005
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The cylinder/piston fit is one of the most important factors governing the success of a home-built model engine. Material selection wise, the home constructor has a number of choices (despite what the plans may say), but each have their own characteristics, advantages, and disadvantages. The most common choices, in ascending order of experience required, are:

There are other combinations, but these have the highest probability of success for the facilities available in the Home Shop--which facilities generally do not include tool-post grinders, nor extensive heat treatment facilities. So the entries below will assume--with the exception of piston rings--that the finish will be produced by turning and honing, with the parts left in the 'soft' condition (although piston rings can be produced without heat treatment too). Even in this state, a well built engine will produce a quite acceptable working life.

Steel liner, Cast Iron piston

This combination gives the first time constructor the highest possibility of producing a runable engine that will have a reasonable working life. Even experienced builders generally prefer this setup for small to medium size sport engines, regardless of the ignition type (say up to 6cc, or .35 cuin). The steel used can be just about anything, but 12L14 will give a superior turned finish that minimises the amount of honing required. The cast iron can be just about anything too, provided is free from chills and impurities. Common "pulltruded" gray
cast iron is quite ok. Fine grained, spheroidal is better, and centrifugally cast "Meehanite", if you can get it, is best of all. While all cast iron is "dirty" to turn due to the fine particles, it can be honed to a very fine surface finish by a variety of methods.

The important things to achieve when using this combination is that the bore should be tapered, wider below the exhaust ports. As a rule of thumb, the taper should be in the order of 0.0015" to 0.002" per inch of working stroke, but it's not that critical. In actual fact, it's hard to produce a fully parallel bore! So this set-up is ideal for beginners. The sequence is:

1. Bore the cylinder from the bottom opening, achieving the finest finish possible. Do not be tempted to try and ream a cylinder bore.
2. Cut the cylinder ports and deburr the inside openings as best you can with a fine Swiss pattern file. Don't go overboard as any deep scratches will have to be honed out. We simply want to prevent the burrs chewing up the hone, and prevent broken off burrs scoring the cylinder itself.
3. Hone with an expanding hone (see the page on Cylinder Honing for details).
4. Turn the piston diameter to be about 0.0015" larger than the lower bore diameter. Finish the

piston interior, then drill and ream for the wrist pin.

5. Hone this piston until the crown will pass the top of the exhaust port, then jam in the tapered bore when the liner is pushed by hand onto the mandrel mounted piston.
6. That's all! You're done.

This "TDC Pinch" assures the assembly will have a good initial compression that quickly wears into a good running fit with a delightful 'bouncy' feel when flipped over. Peter Burford calls this a *Run-In, Peak, Run-Out* fit, and he's right--but the "peak" will be enough for a couple of seasons of sport use, and most home build engines get less use than that.

In summary, the steel/cast iron combination is simple to finish with a high degree of certainty of success. This makes it the favoured choice be beginners and experts alike.

Cast Iron liner, Cast Iron piston

This combination was much favoured of yore by the likes of ET Westbury. It is essentially similar to Steel/Cast Iron and I rate it higher in difficulty only because of the brittle nature of thin walled cast iron turnings. Because of this, the liner requires care and a bit of prior experience in workholding. In addition, the soft nature of the two components (with 'like' running in 'like') results in a shorter working life unless the liner is treated.

Westbury favoured a technique called 'carburising', as described in his booklet Building the Atom Minor Mk III. In this process, the cylinder is roughed out, then the bore is finished, but not honed. It is next packed with case hardening compound using a bolt and two large washers to cover the ends. The assembly is brought to cherry red, soaked for 5 minutes, then allowed to air cool. It is then finished on the outside, the ports cut, and the bore honed as above. The process increases the carbon content for a few thou of depth, making a change in the crystalline structure that extends the life of the combination. It is not "case hardened" as such, and is significantly softer, but the results are worthwhile.

In summary, the combination provide no significant advantage (IMHO) over steel/cast iron apart from authenticity on certain ETW engines. Plus cast iron is expensive, and making a cylinder of the stuff will require lots of sincere lathe cleaning afterwards. Avoid it unless you are a dedicated purist, or masochist.

Steel liner, Steel piston

At the time this page is being written, my experience with this combination is a total sum of three engines. One of these was made long before I knew any better, and standardized on the steel/CI combination. This was an ED Baby 0.46cc restoration done in 1996, and I was always amazed that it ran as well and started as easily as it did. Late in 2004, I tried the combination again on the Pepperell and Mills P75 replicas (as reported in the January 2005 Model Engine News page). Peter Burford, engine manufacturer, and son of Taipan designer Gordon Burford who had managed the Taipan plant in the 70's saw my comment and emailed some very apt observations about this combination. Peter:

I think both steel and cast iron for the piston have merit and tried both in this engine [the PB .33, ed].

A steel piston is fitted with clearance at TDC and will always have an oil film, and a better and extended life--without the **"run-in, peak, and run-out"** *cycle exhibited by a CI piston. Steel will also have a better transfer seal with less cylinder taper ("almost" none above the ports), and can have a thinner, lower mass piston at the same strength. I prefer both components to be hardened, with the piston tempered to 10 Rockwell C points lower than the liner to minimise galling (although I guess that ideally they should be made of different alloys or hardened differently so as to have a differing grain structure--CI has* *this of*

course).

That said, a steel/steel engine may require a higher oil %age for starting compression. The cylinder/piston fit, finish and geometry must be of a higher standard. No misalignment can be tolerated in construction or operation. I have built my diesel as squarely as possible and not with any bias to allow for distortion by heat or power stroke. Very hard for us to prove the merit of this and other features, like offsetting the cylinder axis and etc. I guess these must be initial design decisions.

Overall, I think that steel is more "elegant" and should be better. CI and taper is an easier, more forgiving and more economical production choice for the converse of most of the above reasons and possible gives a better performance in many cases.

I didn't quite get what Peter was saying in relation to bias and squareness. I always build as square as I can, but of course it's more subtle than that. Here's part of Peter's expansion on the topic:

The greater taper used with CI allows misalignment of crank to cylinder, piston axis to gudgeon axis, 'rod bores and shaft journal axis to crankpin axis without binding on the sides of the piston skirt. Increasing the "running clearances" helps too. The tapered liner/CI path lets it all run in OK and work well. The parallel/steel path needs the construction accuracy stepped up a notch or two, particularly when using more wear resistant materials, finer surface finishes and closer fits.

Hence my observation that taper/iron may have been found to be better in many cases.

And, indeed, all our 'cases and cantilevered cranks must distort somewhat with load and thermal expansion. Do we build in an allowance for this? It is often done, but it is a decision like 15 bore and 14 stroke that is made at a design stage and possibly (probably?) not proven to be better--although it MUST be better to be square when running, I wonder who has measured and proven this? We all know that design decisions and sizes determined by available threads, materials, machine collets, etc cannot possibly be ideal (a perfect
'rod length just happens to be an exact fraction of an inch or so many mm? Yeah, right!) I have commented that our well made [Taipan] *production engines always ran better than our best prototypes. So, who has the resource and ability to prove the design features? Taper/CI may work well for a whole bunch of reasons.*

I like the mental exercise, but designing, experimenting and producing a performance competition engine is beyond my present resources. Hence my settling upon a good design and determining to make it really well.

Food for thought (and thanks, Peter). Both of my experiments in this direction ran well and did not seem to exhibit the 'sag' a taper/CI setup exhibits as it warms up--quite understandably, in retrospect. But as Peter says, they require more precision in construction, so I'll go on recommending a CI piston in a tapered steel liner for builders who are just getting their model engineer's feet wet, but suggest those who are confident in their abilities to consider a steel/steel setup as an alternate.

Steel liner, Aluminium piston with Cast Iron ring(s)

I've rated this combination highest in complexity and need of prior experience, but it's not exactly a quantum leap; the techniques could be mastered by talented novices who are careful workers and not reluctant to make a few of something to get it right. The Feeney 15cc Four-stroke Construction Series gives quite a detailed account of an engine that uses this combination, so I'll just add a few observations here:

- Don't try honing aluminium. Besides, a ringed piston does not need it. Turn it to be 0.002" undersize per inch of bore and all will be well. Relieve the band above the top ring up to the crown another 0.001" if

you like.
- Use the George Trimbal method to make and temper your rings
- Bore and hone the liner as parallel as you can. An auto-parts store break-hone will help achieve this, and leave a nice cross-hatch pattern in the bore that is favoured for oil retention.
- Sections of aircraft chrome-molly tube can be honed easily to an excellent liner for this type of engine.

In summary, not a combination for the absolute, raw beginner, but not that difficult either. Best suited to larger engines--say with a bore 5/8" and upwards. Carried out with care and precision, the combination will produce an excellent, long lasting engine that can be quickly reconditioned with a light re-honing and new rings--slightly larger if necessary.

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