Nikasil® and Alusil

A primer on some of the more common specialty coatings and cylinder materials found in small displacement engines

BY **JOHN GOODMAN**

This issue of ***Engine Professional*** is dedicated to specialty engines and niche marketing opportunities. Part of that market involves small displacement engines of all types and configurations. Past experience with these small bore engines has demonstrated a need to understand materials and coating in a way quite different from the run-of-the-mill gasoline engine. Motorcycle, water sport, snow mobile, off-road, stationary power plant and other specialty engines offer a machine shop many high profit opportunities. What has generally kept shops from exploiting these niche markets is a lack of knowledge on how to approach it, a clear understanding of what is required by way of equipment and an understanding of materials and coatings used in the manufacture of these engines.

We will attempt to give the reader a primer on some of the more common coatings and cylinder materials that can be found in these specialty engines as well as many automotive engine applications.

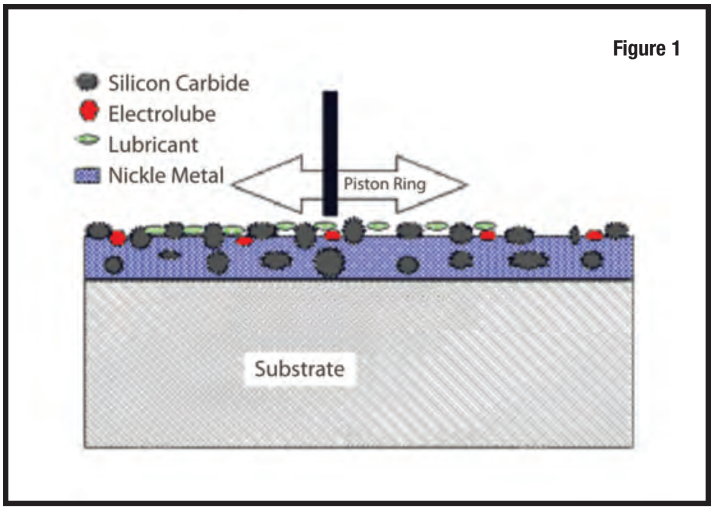
Background

Any shop considering a cylinder repair that has been coated with Nikasil® should be aware of a few material properties and some of the confusion surrounding them. It will not be the purpose of this article to cover many manufacturing details but developing application and machining do's and don'ts will be fundamental.

Let's begin by covering what Nikasil® is. Nikasil® or NiCom® (1967 Mahle trademark) is electrodeposited oleophilic nickel silicium carbide coating. Simply put, it is a nickel plated silica carbide coating often applied to aluminum cylinder bore IDs but can be used for many applications where tight tolerances and superior wear surfaces are indicated. The oleophilic feature of Nikasil® gives it a natural tendency to absorb oil, which in turn helps the oil retention of the coating. Although there are several proprietary formulations of nickel plated silica carbide, application parameters remain the same for all of them.

What Nikasil® and other similar coatings are not remains the center of confusion. Alusil's like Lokasil®, Mercasil® and other high silica substrates are not coatings at all but rather aluminum metal alloys. These alloys have also been referred to as hypereutectic aluminum due to the percent of silica particles contained in the alloy. It is a subtle distinction but Alusil alloys do not contain silica carbide like nickel plating does. Instead of silica carbide, Alusil employs glass-like silica particles similar to sand. Beside silica particles, other hard particle formations are built into the alloy through smelting. These other hard particles can be regulated in size and shape depending upon perceived need.

Nikasil® is also not to be confused with plasma spray cast iron or carbon coatings. Spray cast iron has been used on aluminum cylinder bore ID's as a cost-effective and efficient wear surface. But spray cast iron is much softer than Nikasil® and subject to greater wear. A quick glance at Nikasil® and spray cast iron does not reveal many differences



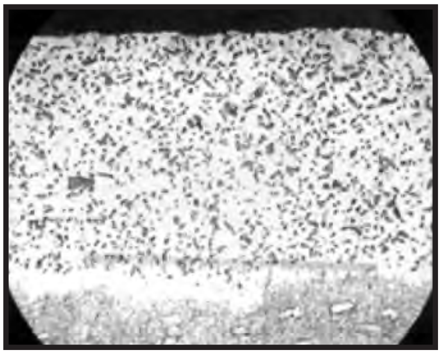


Figure 2: Photomicrograph of Electrosil plated cylinder bore

because both have a grey look to the surface so further investigation is necessary to determine what coating you are working with. Carbon coatings are much easier to identify as they are much darker (almost black). Generally, carbon coatings are not found in cylinder bore ID's but have been used successfully in that application.

Physical Properties

Nikasil®

As has been mentioned, many variations of Nikasil® like Elnisil®, Kanisil®, Electrosil® and SCEM or Suzuki Composite Electro-chemical Material are available from a variety of manufacturers but generally, these nickel silicon carbide composites use about 14% silicon carbide with the rest in nickel and other additives as binders. This would be similar to conventional vitrified abrasive material where ceramic binders are used to hold abrasive crystals in place. Figures 1 and 2 are representations of one type of nickel silicon carbide composite provided by Electrosil Performance Cylinder Technology in Melbourne, Australia.

By drawing a comparison to vitrified abrasives, one might conclude that Nikasil® is an abrasive and by some definitions, it could be. The reason it is not stems largely from low crystal density and the nickel binder covering all but the microscopic peaks of those crystals. These silicon carbide micro peaks are often smaller than oil molecules which reside between crystals and allow pistons and rings to slide easily along the cylinder surface. I suspect this is one of the reasons Nikasil® exhibits greatly reduced friction for sliding seal components such as pistons and rings.

Alusil

Although not a coating, some hypereutectic aluminum alloys suggest by name that they possess Nikasil® properties. Lokasil®, Mercosil® and Silumal® are but three such alloys and often confused with nickel silicon carbide composites. For a more detailed look at this alloy, I would refer you to the April-June 2008 issue, pages 20-26 of Engine Professional magazine and read Tim Meara's article. Tim is Sunnen Products Senior Honing Technician and explains in detail all discreet features of Alusil. It is vital that shops do not mix coatings and alloys together when determining best course of action to take with a repair or machining operation. I often hear machinists speak about preparing a hypereutectic alloy as though it were Nikasil®. This can lead to disastrous results and ultimately blame the alloy or coating for a failure. So let's take a closer look at these hypereutectic alloys often referred to as Alusil.

KB Pistons describes hypereutectic aluminum alloy like this: Silicon additions to aluminum are very similar to adding sugar to iced tea. Silicon can be added and dissolved into aluminum so it too becomes inseparable from the aluminum. If these additions continue, the aluminum will eventually become saturated with silicon. Silicon added above this saturation point will precipitate out in the form of hard, primary silicon particles similar to the excess sugar in the iced tea.

This point of saturation in aluminum is known as eutectic and occurs when the silicon level reaches 12%. Aluminum with silicon levels below 12% are known as hypoeutectic (the silicon is dissolved into the aluminum matrix). Aluminum with silicon levels above 12% are known as hypereutectic (aluminum with 16% silicon has 12% dissolved silicon and 4% shows up as primary silicon crystals).).

A hypereutectic aluminum-silicon alloy produced by a powder metallurgy technique comprises 12 to 50% by weight of silicon, 1.0 to 5.0% by weight of copper and 0.01 to 0.05% by weight of phosphorus, the content of calcium (Ca) as an impurity being controlled to be 0.03% by weight or less. Hypereutectic aluminum-silicon alloy exhibits excellent mechanical strength and is therefore used for manufacturing pistons and other engine components.

A hypereutectic aluminum-silicon casting alloy used in cylinder blocks for marine engines is composed by weight of 16% to 19% of silicon, 0.4% to 0.7% magnesium, up to 0.37% copper and the balance in aluminum. With the stated silicon content, this alloy has good fluidity and the precipitated silicon crystals provide excellent wear resistance. In addition, the alloy has a narrow solidification range of less than 150° F., thereby providing the alloy with excellent castability. The copper content is maintained at a minimum so that the alloy has improved resistance to salt water corrosion.

These expressed features of Alusil have gained popularity as a structural material and less so as a sliding seal wear surface. But many engine manufacturers of all sizes and types use Alusil as a wear surface too and should be treated accordingly. *(continued on next page)*

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Original Equipment Direct Injected Coated Piston for General Motors 2009 2.0L Ecotec Turbo Engine.

Machining and Preparation

Most of the confusion surrounding Nikasil® and Alusil exists because they are both used as cylinder ID surfaces for exactly the same application. Even their name suggests they are the same so it is easy to mix them up and treat them identically when machining. So how do we machinists and assemblers treat these two distinctly different processes?

Let's start with Nikasil®. Nickel silicon carbide composites are applied as a thin coating of about .002"-.006" thick. We are told that anything thicker than .006" and the coating may lose some of its elasticity and become brittle. So, depending on how much thickness you have to work with, careful honing is a viable process to restore a factory surface finish. If you cannot determine coating thickness, assume it is thin and treat it as thought it were no more than .002" thick. Due to the thin nature of this coating, boring the cylinder to the next oversize will remove the coating entirely. Under these circumstances, the block or cylinders should be sent to a facility that specializes in re-coating with nickel silicon carbide.

Mahle recommends honing no more than .001" from Nikasil® coated bores and only to restore cylindricity to any wear areas. If wear is greater than .001", it is advisable to have the coating stripped (in many cases this is a simple electro chemical process and does not require boring) and fresh nickel silicon carbide applied. Check with the supplier of coating material for correct honing stones for this process. Please note that piston to wall clearance for Nikasil® coated liners and hypereutectic pistons can be as close as .0008" so careful attention to detail is advised.

Alusil is a different material and how this substrate is honed leaves little room for error. So as not to be redundant, I would refer you once again to Tim Meara's article on honing Alusil.

One final note on machining Nikasil® coated cylinders; if decking has to be done, this may but not always require a re-plate of the bore ID. Many cylinder coaters bring Nikasil® over and around liner edges. This is done to tie the coating at both ends of an edge and reduce potential separation or flaking. Engine manufacturers can do this because they mask off coating just inside the head gasket sealing ring area of the cylinder. Decking will eliminate this edge feature and may leave the coating unsecured.

Pistons, Rings and Coatings

Years ago, GM used a hypereutectic alloy in their Vega four cylinder engine. That engine had its own problems but rebuilders were left in the dark as to how rebuilding should take place. Given the relatively high tech nature of materials and machining vital to restoring wear surfaces in these cylinders, rebuilders experienced failures when employing tried and true methods used for cast iron blocks. Even when correct surface generation processes were employed, failures continued. The fix then was to sleeve with cast iron liners and install standard aluminum pistons and garden variety cast rings.

So what was missing in this exercise? What eventually became clear was that piston skirts had to be coated and ring faces should be barrel shaped if Alusil cylinder bores are to be retained as a wear surface. When this news finally hit the rebuilding industry, rebuilders already had a workable fix by sleeving with cast iron liners. But that fix is not always possible with modern engines using Alusil as a sliding seal or wear surface.

Early in the process, piston coating for use in aluminum cylinder bores became know as "tining". As it turns out, "tining" piston skirts was indeed a thin layer of plated tin used as a wear or scuff barrier between aluminum pistons and aluminum cylinders. "Tining" then became a euphemism for several piston coatings that acted as wear barriers. Some manufacturers used a variety of coatings that included nickel–tungsten (Ni–W) plating, electroless Ni plating, Ni–P coatings with ceramic particles such as boron nitride (BN), SiC, or Si3N4, as well as titanium nitride physical vapor deposition (PVD) coating, diamond-like carbon (DLC) coating, spray cast iron and hard anodizing. Not all of these coatings proved reliable against scuffing Alusil cylinder bores and were eventually replaced by more robust piston coatings we see in use today.[1]

Due to the abrasive nature of Alusil and the affinity aluminum has to itself; this coated barrier greatly reduces seizure of component parts. A stock aluminum piston would simply not survive even in a well prepared Alusil cylinder bore. Further, barrel shaped ring faces were used to glide across correctly honed and etched silicon particles without dislodging them. Beveled ring faces utilize a scraping action which may be detrimental to an Alusil wear surface. Exercise caution when selecting a suitable ring pack for use in Alusil bores.

Further, many different ring materials are used for Nikasil® and Alusil but some of the better ones are Gas Nitrided, Ion Nitrided or titanium coated tool steel. There appears to be some consensus that using a barrel shaped ring for either Nikasil® or Alusil cylinder bores works best. However, always go with the coating or cylinder alloy manufacturer's recommendation for a suitable ring pack.

Cautions

Some of the early factory Nikasil® coated engines suffered piston seizures. The culprit turned out to be use of high sulfur gasoline sold mostly in Europe. Even moderate use of this gasoline began the destructive process that only got worse with time. We won't go into the chemical reasons why nickel breakdown occurs in the presence of sulfur but it is a very real problem nonetheless. Some engines with Nikasil® coated liners have been run successfully on LPG due to its extremely low sulfur content. The caveat here is to question your customer about fuel to be used especially if a nickel silicon carbide coating is what you are working with.

Additionally, both Nikasil® and Alusil have been used simultaneously by several engine manufacturers. Porsche, Mercedes-Benz and BMW offered both in different engine families within the same model year. In some cases, Alusil may be the parent cylinder material that is coated with Nikasil® or some other wear surface. Be sure to correctly identify the material or cylinder coating you are working with before starting any job.

Applications

This list is far from complete but should give you an idea of how many engines use or have used Nikasil® and/or Alusil for cylinder bores:

- Chevrolet LT5 used in the Corvette ZR-1
- Chevrolet Vega 2.3 and 2.0 Cosworth
- Citroen Visa twin
- Citroen GS birotor wankel
- BMW M52 inline six
- BMW M60 V8
- BMW R80GS
- Ferrari F50 V12
- Ford RS200
- Honda RS125R
- Honda XR650R
- Jaguar AJ-V8 check series and VIN numbers
- KTM LC4
- Lambretta TS1
- Lotus Esprit Turbo 2.2
- Maserati Biturbo 2.0 V6
- Moto Guzzi 850 T3
- NSU Ro80
- Porsche 912
- Porsche 911 1973 on (excluding 1975-1978 911S)
- Suzuki RGV250
- Yamaha R1 1000cc

There are many more engines out there than those listed above and more will be using these coatings and alloys in the future. They can be successfully and profitably renewed using tools and equipment you already own. Only correct identification of materials and careful attention to machining are necessary to do these jobs successfully.■

[1] Yucong Wang & Simon C. Tung (January, 2000). *Scuffing and wear behavior of aluminum piston skirt coatings against aluminum cylinder bore*. GM Powertrain, General Motors, Saginaw, MI 48605-5073, USA; GM R&D Center, General Motors, Warren, MI 48090, USA.