Cylinder Bore Scoring in Hypereutectic Aluminum Blocks

BY **CHARLES L. NAVARRO**

As manufacturers search to find ways to extend the life of the internal combustion engine, we are seeing a trend of engine downsizing. Reduction of cylinder count resulting in reduced displacement and engine weight coupled with forced induction is providing sizeable gains in fuel economy with equal improvement in horsepower. One of the biggest changes with modern engines has been the elimination of iron liners which allows for tighter bore spacing and larger cylinder bores as well as for a reduction in water jacket and total cooling system volume because of the increased thermal efficiency offered by an all-aluminum engine.

A great example of this is Mercedes M139 engine which makes 421 horsepower from 2.0 liters. To be able to accomplish this, an all-aluminum engine with optimized thermal and volumetric efficiency is required. With Toyota's 2ZZ-GE engine they were able to increase horsepower by 26% and torque by 5% with no increase in displacement by eliminating iron liners. Not having an iron liner to impede heat transfer allows for improved performance. Like Toyota, Honda also developed their own hypereutectic aluminum engine block technology that was first used in the Prelude Si and subsequently in their NSX and S2000 models.

Manufacturers like Porsche have successfully used all aluminum engines for over half a century by using thin coatings applied to cylinder bores, starting first with hard chrome and later using Nikasil. However, it was Chevrolet with the Vega where the first liner-less aluminum block was used. The Vega used Reynolds A390 aluminum (now known as Alusil) where through a special preparation process the silicon particles in the aluminum were exposed in the bores. This also required the use of an iron-clad to prevent galling from the aluminum piston running in a raw aluminum bore. The way this system works is the oil goes around the silicon particles and allows formation of the required tribofilm to support travel of the piston and rings in the aluminum bores. It is worth noting that shortly after the Vega, Porsche also used Alusil in both their 944 and 911 models with great success, with many of those engines still running flawlessly almost 50 years later. Many other manufacturers including Mercedes, BMW, and VW/Audi have and still use Alusil to this day.

However, when the coating on the piston is compromised or too many of the exposed silicon particles in the bores become damaged and fracture, the tribofilm can no longer support normal operation. When this occurs, bore scoring is the result. This is not to be mistaken for seizing of the piston in the bore, however there

Failed piston skirt coating.

is often significant metal transfer between the piston, rings, and bores when bore scoring occurs. Symptoms typically include piston slap and significant oil consumption; increased iron, aluminum, and silicon in the oils as detected by using used oil analysis can also be early indicators of bore scoring which can be verified by bore scoping cylinders.

Starting with the Boxster in 1997, Porsche used a new process developed by the creators of Alusil called Lokasil. To simplify things, we refer to Lokasil as localized Alusil. Where normally a whole block is cast out of Alusil, Lokasil uses a freeze cast liner inserted into the mold where the pre-form has silicon particles embedded in resin. When the molten aluminum is injected into the mold, the resin is burned off, leaving a thin area of high silicon content aluminum centered around the cylinder bore. The cylinder is then prepared the same way you would with an Alusil bore to expose the silicon particles. This process was revised by Kolbenschmidt several times with Lokasil II and then Lokasil III, however problems with this process continued and Porsche went back to using Alusil in their sports car engines for the 2009 model

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year. These Lokasil blocks used from 1997 through 2008 can suffer a multitude of issues including cracking and scoring.

The big difference between the modern Lokasil and Alusil engines and older ones are in the process used to prepare the cylinder bores and with the coatings used on the pistons. Originally a lapping process with an etching paste was used to remove the aluminum from the bores, effectively exposing the silicon particles. The more common process used which is faster and more cost effective is a mechanical one, however care must be taken to not fracture too many of the silicon particles, which could be a reason failure is more common with these newer engines. Likewise, the pistons used to get an iron clad plated which was later replaced with more environmentally friendly coatings that have not held up as well as previous processes. Another variable is the reformulation of oils and the push for thinner oils to improve fuel economy, all of which have a detrimental effect on wear.

Conventional thinking would say the more effective way to repair an engine with scored bores would be to put in an iron liner, however most modern engines with FEA optimized crankcases do not have sufficient parent metal in them to allow installation of an iron liner. With models where the cast in aluminum liner can be machined out and a wet liner fitted, other issues can occur stemming from dissimilar material expansion rates including head gasket failures, cracking of blocks due to the

Close-up of bore scoring on Porsche M96 block.

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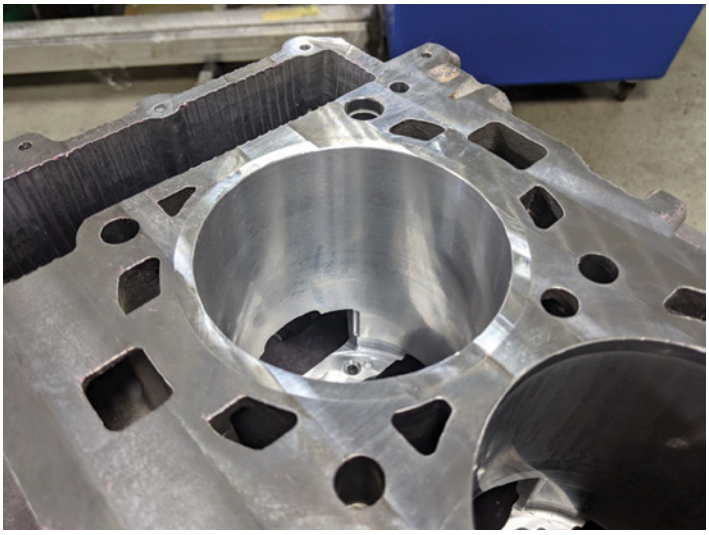

Closed deck Porsche MA1 block with aluminum dry sleeve.

Porsche M96 block with aluminum wet sleeve with SUMEbore APS coating.

required press fit, and not least performance and cooling issues. Several companies including LN Engineering utilize nickel silicon carbide plated aluminum dry and wet sleeves to repair aluminum engines with bore scoring or other cylinder failures.

Where sleeving is not required, oversized pistons with the proper coatings can sometimes be sourced from the OEM that are specifically designed for use in engines with hypereutectic cylinder bores. Preparing these bores also requires special tooling and processes as they do not get honed conventionally. Alternatively, the cylinder bore can be slightly bored out to allow for application of Nikasil plating. Processes now used by OEMs like APS and PTWA coatings will soon also be available to the aftermarket, providing more options to repair hypereutectic aluminum blocks without having to make compromises in the area of performance

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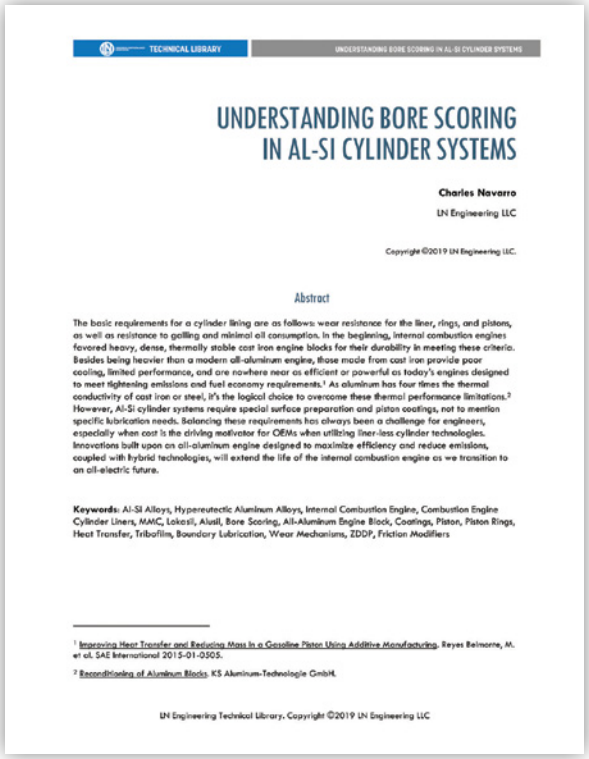

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UNDERSTANDING BORE SCORING IN AL-SI CYLINDER SYSTEMS

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Abstract

The basic requirements for a cylinder lining are as follows: wear resistance for the liner, rings, and pistons, as well as resistance to galling and minimal oil consumption. In the beginning, internal combustion engines favored heavy, dense, thermally stable cast iron engine blocks for their durability in meeting these criteria. Besides being heavier than a modern all-aluminum engine, those made from cast iron provide poor cooling, limited performance, and are nowhere near as efficient or powerful as today's engines designed to meet tightening emissions and fuel economy requirements.[1] As aluminum has four times the thermal conductivity of cast iron or steel, it's the logical choice to overcome these thermal performance limitations.[2] However, Al-Si cylinder systems require special surface preparation and piston coatings, not to mention specific lubrication needs. Balancing these requirements has always been a challenge for engineers, especially when cost is the driving motivator for OEMs when utilizing liner-less cylinder technologies. Innovations built upon an all-aluminum engine designed to maximize efficiency and reduce emissions, coupled with hybrid technologies, will extend the life of the internal combustion engine as we transition to an all-electric future.

Keywords: Al-Si Alloys, Hypereutectic Aluminum Alloys, Internal Combustion Engine, Combustion Engine Cylinder Liners, MMC, Lokasil, Alusil, Bore Scoring, All-Aluminum Engine Block, Coatings, Piston, Piston Rings, Heat Transfer, Tribofilm, Boundary Lubrication, Wear Mechanisms, ZDDP, Friction Modifiers

[1] Improving Heat Transfer and Reducing Mass in a Gasoline Piston Using Additive Manufacturing. Reyes Beimonte, M. et al. SAE International 2015-01-0505.

[2] Reconditioning of Aluminum Blocks. KS Aluminum-Technologie GmbH.

The technical paper "Understanding Bore Scoring in Al-Si Cylinder Systems" can be downloaded from the LN Engineering website at www.LNengineering.com/education.html.

or longevity. To successfully repair and rebuild these modern engines it is ever more critical that modern processes and technologies are used to ensure satisfactory results.

For a more in depth analysis of the modern all-aluminum engine and the challenges associated with them, the technical paper "Understanding Bore Scoring in Al-Si Cylinder Systems" can be downloaded from the LN Engineering website at www.lnengineering.com/education.html.■

Charles L. Navarro is the co-founder and president of LN Engineering and is a specialist in the area of Porsche engines with over 20 years of experience. His company, based out of Chicago, IL, provides services and manufactures products for the automotive aftermarket. For more information, go to LNengineering.com.