Cylinder Sleeves

BY **DAVID CLINTON**

Before we could have sleeves, we needed a developed metallurgical industry to provide us with the proper kind of iron to act as a wear surface inside the engine cylinder.

As might be expected, the "Iron Age" was born thousands of years ago as humans discovered the earth's crust is abundant with iron ore and put it to use as iron utensils, weapons, shoes for cloven animals and the like.

Casting and forging began in the Seventeen hundreds with iron use in farm implements, water wheels and started to mature as metal smiths discovered the use of blast furnaces, smelting and how to process chemical additions to the iron to improve its use and provide for more applications.

By the 1800s, casting was starting to mature when the creation of "pig iron", the essential ingredient of iron, was perfected in pure form without impurities. Even today "pure" pig iron is the foundation of good cast or ductile iron.

"As cast" cylinder sleeves still are made today for various applications but mostly in our industry the sleeves are manufactured using a centrifugal process, sometimes referred to as "spin casting" Centrifugal casting is a age old process

A red hot cylinder sleeve being produced on its way out of molding die after metal is formed into raw casting.

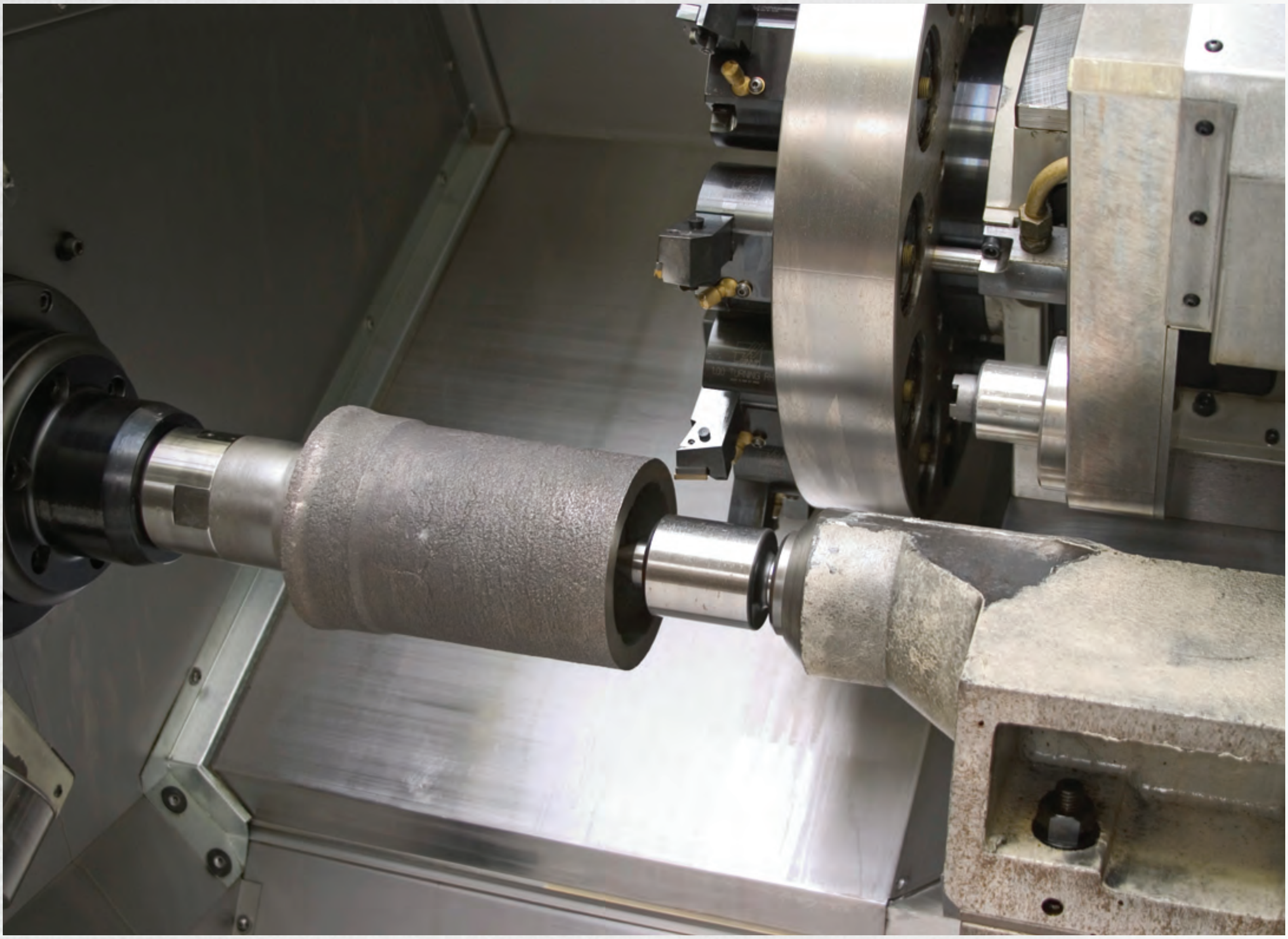
having begun in Europe during the 1800s. This type of casting is used in jewelry, and various types of steel and pipes.

Centrifugal casting for sleeves came of age in the USA during the 1950s as more engine rebuilding and restorations demanded cylinder liner material be as good as the parent cast iron blocks of the day. In the 1960s, the OEM market began the introduction of aluminum engine blocks which ultimately required the large scale investment in cylinder sleeve production to support the new higher quantity of aluminum blocks.

Today we have many choices of sleeve material from aluminum, steel, composite, metal matrix, cast iron and ductile iron. In engines there also choices of bore materials from coated aluminums to sprayed on iron.

Whatever the surface within the engine cylinder it MUST be a wear surface able to withstand high temperatures, long service duty and resistance to ingested debris or containments in the oil. The description of the most sever service is probable diesel engines for trucks and off road earth moving equipment. Sleeves within these engines are very high grade irons and induction hardened to over 400Bhn.

Conventional engine sleeving began with the need to repair cast iron engine blocks with cracked cylinder wall(s). The process was straight forward; a boring bar was mounted on the block, a larger hole was made, as long as the increased bore did not break into the water jacket, and a sleeve with 1/8 ,3/16, or ¼ wall repair sleeve was forcibly inserted into the newly bored hole with a substantial interference fit. The sleeved hole was then re-bored and



After the cylinder sleeve has been produced in the die, it is then machined to the proper outside diameter during the raw cast machining process. Some sleeves are machined for upper flange diameters, as well as upper bore and lower bore diameters.

honed back to piston size. This type of engine repair has mostly disappeared as the result of the OEMs total conversion to aluminum engines and the emergence of the aftermarket block manufacturing business. This transformation in the sleeve supply market has caused all the sleeve manufactures to refocus on core markets such as Performance, after market supply to specialty markets, racing, and engine specialty shops.

In the "good old days" when we pounded sleeves into the blocks, little concern was given to "cylinder seal". During the 50s and 60s engines were equipped with breather tubes to evacuate crank case pressure. The result was a constant black oil film in the center of the roadways and caused motorcyclists to avoid the center of roads like the plague. Later on came PCV valves causing the engines to ingest the crankcase particulate and consume it in the intake system. No one ever gave thought to the root cause of this phenomenon, lack of cylinder sealing. Back then one quart of oil consumed per thousand miles was considered okay.

Today cylinder seal is the KING of all engine building from the OEMs to NHRA drag racing. Pan pressure is the telltale sign of cylinder leakdown. 0 leakdown is hardly attainable but as little as ½ % is routine in some engine build disciplines. The OEMs have gone to much tighter clearances, on bearings, piston to wall, and the industry as a whole has been adopting razor thin piston ring cross sections to increase sealing, reduce friction, and provide for less rotating mass. Oil viscosities have thinned to the point that the OEMs are now specifying 0 weight oil, whatever that is.

So finally we get to SLEEVES… Are they still needed and relevant in today's engine world? Absolutely! The sleeve is the basis of the marriage in the cylinder between the cylinder wall, the piston rings, the piston and the film of oil on the surface which is the glue of the sealing process.

The beginning of a sleeve's life starts with the chemistry and the desired material. Conventionally we will concentrate on cast iron or ductile iron and the various grades of each. All other types of sleeve material i.e. steel, aluminum require special treatments, surface coatings or special hardening to create a surface hardness acceptable to act as a cylinder sleeve.

Presuming centrifugal casting the process begins with the foundry men preheating the furnace and ladles. Based on the selection of the material type, pig iron is the first in the furnace and when it becomes molten the remaining chemicals are added in a manner and formula which will assure an outcome of chemical percentages that when checked after the pouring and cooling will reflect what is necessary to assure a homogenous and stable metal product. As a for instance, Cast Iron will typically end up with Carbon @ 3 to 3.5%, Mn @ .45 to .90, Si @ .12, P @ .12 max. This would equal, approximately ASTM-A48 Class 30 cast iron. This material would spec out at 30.000psi Tensile, hardness @ 196-249 Bhn and generally be graphite in micro structure. This material will also be very brittle but provide a good cylinder wall wear surface, easy to bore/hone and straight forward break in.

The SAE society through the ASTM guides generally will specify mechanical properties, chemical content and micro structure which determines tensile and yield properties of each material. So if you were searching for class 60 cast iron the ASTM standard would provide you a document to analyze all the data. In most material specifications, especially aluminum, or steel, you can receive a printed certification of the material specs, the lot number, foundry date etc. In the casting world this documentation may provide the same data but without certification. This makes the foundry process critical to assure a dense consistent micro structure without porosity, occlusions, or hard spots. This is the challenge for all foundries because unlike steal the cast part does not necessarily reveal all these things until the end.

I liken casting with a furnace, ladle and technicians/chemists as like my Mom baking an apple pie; the chemicals must be added in a precise, orderly fashion at particular times and properly mixed to attain the material specs the foundry is looking for. The temperature of the pour must be maintained precisely and the mixture must continually be degaussed (mixed) to assure chemical balance.

Now in the case of ductile iron (nodular iron) we add much more complexity of the mixing, pouring and add the term inoculation. Inoculation is the final added at peak temperature with Magnesium. This single event converts the molten material to a "nodular" structure unlike cast iron which is a flake structure.

Ductile iron was born in the 1940s with a research project at International Nickel Co. by Keith Mills. Many firms were searching for ways to replace steel with a suitably strong product but which would be less expensive. Because cast iron is brittle, the search for a strong cast material with "ductility" began. During the early 1940 time frame there was rationing and shortages of alloys thought to be used in cast iron to improve the ductility factor. By war's end, two crucial elements became available, Cr (Chromium), and Ni (nickel) The development of ferrosilicon (MgFeSi) made the casting of ductile iron easier and more predictable.

In 1949 the first ASTM spec for ductile iron was issued as ASTM A339-51T; this was later replaced with the spec we have today, ASTM A 536 which depicts the various grades and mechanical properties of ductile iron.

What is Ductile Iron? Well basically it is a cast form of iron with steel like properties. Ductility means there is a distortion factor without breaking so the opposite of brittle. This is expressed in the mechanical properties as "elongation" and listed as a % of distortion before breakage. This value ranges from 2-8% typically. There is also a substantial increase in hardness from cast iron, all the way up to 330Bhn without heat treating.

Then we have the strength factor expressed as Tensile/yield in PSI, usually ranging from 60,000 to 100,000 pounds.

Ford was probably the first OEM to use as cast stack molding of ductile iron for rocker arms in 1949 and in 1951 converted to 100% crankshaft production of ductile iron.

One of the uniqueness of the ASTM ductile iron spec is that unlike other materials, no chemistry is called out. This basically gives free rein to the foundries to invent their own recipes. Our firm Darton Sleeves has researched the chemistry for years and this was driven by an inquiry from Orenda Aerospace in Canada, who was searching for an economical ductile sleeve for a V8 engine project destined to become a certified aircraft engine. Darton was selected as the vendor and the requirement was for a sleeve to withstand 1500 hours of use @ 75% horsepower and not wear out! This engine was certified by the Canadian DOT and the FAA in 2001.

This process was a long ordeal with a lot of challenges but we finally succeeded and we supplied the first 100 parts which were destined for robotically controlled engines in test cells which ran 24 hours a day for weeks. At the conclusion of the tests all engine components were evaluated for wear; the sleeves only wore only .002!! Now I know what you’re thinking, my Chevy ran 150,000 miles and was still going strong! The difference is average driving is accomplished at about 20-25% peak power output so your Chevy was basically loafing for 150,000 miles.

All of this was made possible by chemistry and foundry procedures. Today this chemistry is the basis of our top grade of ductile iron (DDI-2007A) we supply to all of our Top Fuel and Funny Car customers. This material is 140,000psi tensile strength, 80,000psi yield, 4-5% elongation and 300Bhn hardness. Also this material is the densest commercial material available at 500 nodules per square mm. Average ductile usually is in the range of 200 nodules per square mm. (More of this data is available at www.dartonsleeves.com.)

Darton is a pioneer in the sleeve business having invented in 2004 and commercializing a radical concept for sleeving engines called MID for “modular integrated deck”. The concept was born out of the engine builder’s desire using OEM engines to increase bore size and still stay within the confines of bore spacing, two diametrically opposed concepts. Sooner or later increasing bore size usually yields weak block structure with thin wall sleeves, sometimes at .060 wall thickness. This just won’t work; to contain combustion the cylinder needs structure and wall (read mass). Remember sleeves will not make up for missing mass, and cylinder distortion and leak down will surely follow.

The MID product effectively re-engineered the block by providing integral and Siamese structure to eliminate bore distortion and provided for a solution by engineering the product as a wet sleeve so they are easily replaced in the field. Just recently Dart Machinery introduced the MID product as an option in their new LS Next aluminum block and the Aluminum SBC. Darton currently has about 50 different applications for the MID. Visit our web site for all the details.

Sleeves are not just “pieces of pipe”; ask any foundry or casting facility about the challenges in the process and they will usually tell you about the “one guy” who makes all the recipes and consistency come true, the process is truly artful. Rodney Dangerfield said it best; all he wanted was a little respect, just like us sleeve guys.

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