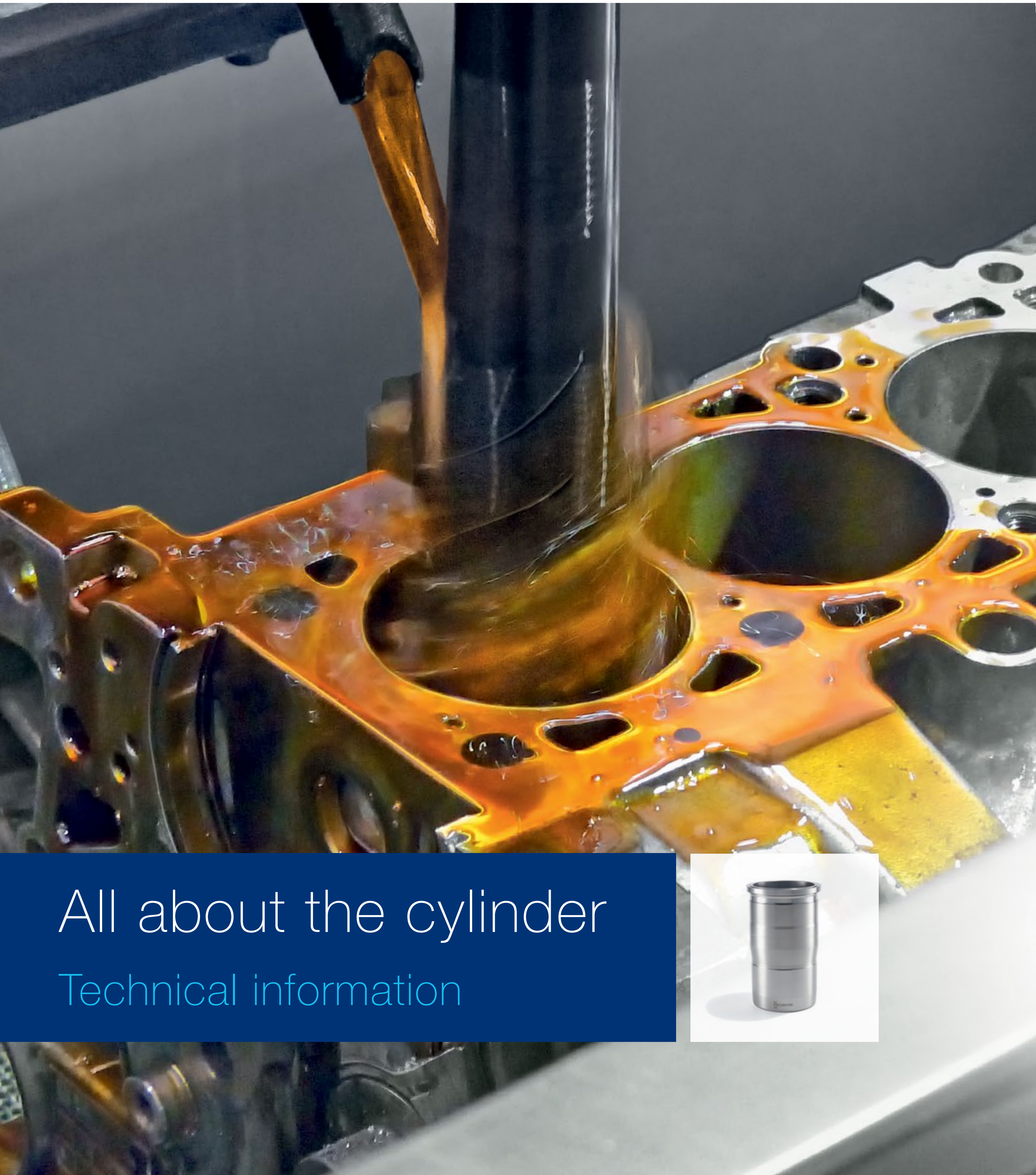
MAHLE



# All about the cylinder

## Technical information

# Preface

*Many engine blocks are scrapped because it is assumed that repairing them is no longer worthwhile. However, the decision of whether or not to refurbish or scrap an engine block should be properly thought out.*

## The following factors should be considered:

- Residual value of the vehicle
- Expected resale value
- Expected remaining service life
- Degree of destruction of the engine block
- Repair costs
- Cost of a replacement engine
- Lack of or limited guarantee or warranty

The final decision, however, is often not made on economic grounds, but rather due to a lack of knowledge. Not all repair options are taken into consideration. We have therefore compiled them in this brochure.

The following chapters describe what needs to be considered by workshops and engine reconditioners, as well as by developers and designers, regarding continuous engine development, machining methods, and technology.

## The brochure consists of four parts:

- The first chapter provides an overview of the different casting processes. In addition, the differences and similarities between aluminum and gray-cast-iron engine blocks are highlighted.
- In the next two chapters, all of the factors, peculiarities, and machining methods for both materials are discussed in detail.
- The fourth chapter covers various measurement techniques and options for testing topography.

All of the dimensions and tolerances given on the following pages are recommendations. The dimensions specified by the engine manufacturer are definitive in all cases.

# Contents

# Overview of aluminum and gray-cast-iron engine blocks

*Selecting the casting process is not limited to manufacturing costs alone. The technical properties and complexity of the part to be cast must also be taken into account. The process chosen must be thoroughly considered, even before the first molds are built. The following is a brief overview of the most commonly used processes.*

## 1.1 Casting processes

### Sand casting

This process is particularly suited for one-off or small-lot production. The smelted material is poured into sand casting molds with inserted sand casting cores, either by pouring or by pumping. The advantage of this process is that the casting is relatively easy to separate from the mold after cooling.

Depending on the method, the sand of the lost mold can be reused for other molds after it has been processed.
**Examples:** machine beds, engine blocks, crankcases

### COSCAST™ process

This patented process is used in particular for the production of precision castings with high finish quality and shape accuracy. The aluminum melt is filled into the mold from below using a ceramic pump and then rotated 180° for precipitation heat treatment. The cores for this process are made of zircon sand.
**Examples:** cylinder heads, crankcases, fuel pumps, and helicopter drive unit components

### Molding sand (green sand)

The modeling material that is placed directly on the model to produce casting molds is called molding sand. The cavity boundary of the mold created in this way must have optimal properties for the actual process. One disadvantage is that sand cores made of molding sand are bonded with clay or mud and have a relatively high moisture content. Because this partially evaporates and is absorbed by the component when the hot metal melt is poured in, the casting is somewhat porous, reducing its mechanical strength.
**Examples:** die-cast parts with cavities, such as cylinder heads with channels

### Core package system (CPS) process

In the CPS process, sand is bonded with a binder, typically resin, to form a sand core. The curing takes place in the furnace or by introducing gas. There are also binders, however, that harden at room temperature. The sands—zircon or silicon—used in this method have a very small thermal expansion coefficient and density similar to that of aluminum. Probably the greatest advantages of the CPS process are, on the one hand, less rework, as the holes and channels can be cast in, and, on the other hand, the weight and material savings.

Disadvantages include the relatively high investment for mass production and the difficulty of cooling critical parts—making it more difficult to cast hypereutectic alloys.
**Examples:** complex engine housings with complicated cores

### Full-mold casting method (lost foam method)

In this process, polystyrene foam coated with a heat-resistant layer serves as the core. When the casting is poured, the polystyrene is gasified. The advantage of this is that complex components with a large number of integrated parts can be formed simply and easily.

The integration of cooling galleries, however, creates problems, as the cooling process has a critical effect on process reliability.
**Examples:** piston rings, turbine wheels, exhaust manifolds, bearing housings

### Permanent mold casting

This is where the casting mold is made of a metal alloy. The casting penetrates into the cavity formed between the core and the mold under the force of gravity. Both the cores and the molds are reusable. The characteristics of this process are very high dimensional accuracy and excellent surfaces, but high tooling costs.
**Examples:** pistons, crankcases

### Gravity die casting

The physical effect of gravity is put to use here. The liquid material is poured into the mold from above and fills the cavities. The inflow velocity depends on the casting height and the method of casting. Both permanent molds and lost molds can be used.
**Examples:** pistons, housings, turbochargers, bearing housings, finned cylinders

### Low-pressure die casting

In low-pressure die casting, the mold is placed above a container holding the liquid metal. The melt is drawn into the casting mold by negative pressure. In comparison with gravity die casting, this process offers several advantages. On the one hand, the casting speed can be adjusted to an optimal level. On the other hand, only a very small runner system is required. This means less rework for cleaning and deburring the raw part. The amount of material required is also reduced. While the runners in gravity die casting can be up to 100% of the weight of the raw part, they are only 5% to 20% in low-pressure die casting.
**Examples:** aluminum finned cylinders, aluminum engine blocks

### High-pressure die casting

This casting process uses permanent molds to produce castings with thin walls. The melted material is pressed into the mold quickly and in a defined manner under high pressure, which ensures that even highly complex molds are optimally filled. At a pressure of approximately 10 to 200 MPa, the form filling speed can reach 120 m/s. This means that even very thin-walled and large-scale components can be produced with a high-quality finish. One disadvantage is that casting requires a permanent mold, so the process is suitable almost exclusively for series and mass production, but not for one-off or small-lot production.
**Examples:** oil filter housings, shift templates for automatic transmissions

### Squeeze casting

This process is essentially the same as “simple” high-pressure die casting, but the melt is filled into the mold through a rise from below at low speed. This allows more effective outgassing, so that gas inclusions are practically eliminated. Subsequent heat treatment improves the material characteristics. The process also enables the use of “preforms,” which are highly porous molded parts made of ceramic fibers. When they are placed in the casting mold, they are infiltrated. This can be used to create new composite materials and generate extremely durable running surfaces.
**Examples:** pistons, thick-walled parts such as bolts

### Semisolid process

This process is characterized by molding in a semiliquid state. It combines the design freedom and production speed of pressure die casting with the quality advantages of forging. Despite its relatively low cost, it produces components with high strength and toughness that are also heat-treatable, pressure-tight, and weldable. The material is injected or cast in a semiliquid state, which produces a microstructure in which the finely distributed, crystallized components are embedded in cohesive melt regions. This gives the component the desired thixotropic characteristic.
**Examples:** transmission housing sections, steering system components, suspension components

### Centrifugal casting

Centrifugal force is put to use here. The melt is poured into a permanent mold (casting die) rotating at high speed and spun out to the internal walls of the mold by centrifugal force, where it solidifies. This can take place in two axes:

- Horizontal centrifugal casting, for example, is used to produce cylinder liners or piston rings.
- Vertical centrifugal casting is used to produce flat components, such as gears or belt pulleys.

One advantage of this process is that the centrifugal force produces a microstructure that is more compressed in comparison with gravity die casting, and another is that it is free of gas bubbles, voids, and impurities that are less dense than the melt.
**Examples:** cylinder liners, gears, piston rings

## 1.2 General information on aluminum and gray-cast-iron engine blocks

Vehicle weights (passenger cars and commercial vehicles) have increased steadily since 1975—by approximately 30% through 2004 for passenger cars alone, despite lightweight designs. The reasons are increased passive safety equipment and a growing need for comfort. But driving resistances increase proportionally with vehicle mass (except for airflow resistance), while reducing fuel consumption is also indispensable in times when raw materials are becoming scarcer. To resolve this conflict, there are only two options with sufficiently high potential for vehicles with internal combustion engines: increasing engine efficiency and reducing vehicle weight.

Engine components such as cylinder heads, brackets, and crankcases are often manufactured from aluminum alloys. The most well known in the automotive environment is the aluminum–silicon alloy, or AlSi casting alloy for short. At a fraction of the weight of comparable cast-iron components, their strength is between 170 and 380 N/mm$^2$. The aluminum has between 0.6% and 21.5% silicon added to it in order to achieve the desired strength, rigidity, and other necessary characteristics. With an Si content of up to ~12%, they are referred to as subeutectic alloys, and above ~12% as hypereutectic alloys. A comparison of densities—7.15 kg/dm$^3$ for cast iron and 2.65 kg/dm$^3$ for AlSi—shows how substantially weight can be reduced by the use of this alloy.

Cast iron, which had been used in all types of engines until a few years ago, is an alloy of iron and carbon with a carbon content of at least 2%. Other alloying elements are added, such as silicon. The most significant cast-iron materials are:

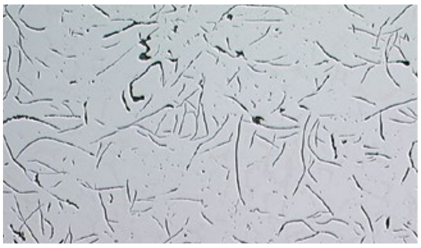
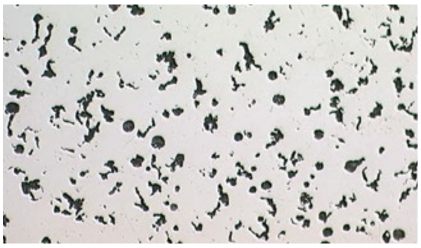
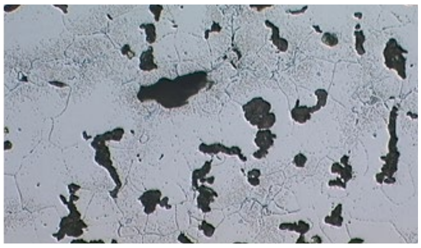
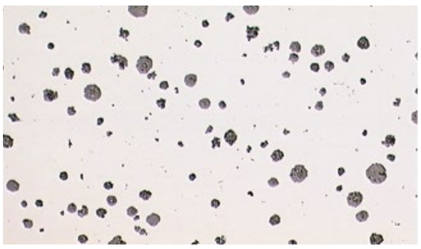
- Cast iron with lamellar graphite (GJL)
- Cast iron with vermicular graphite (GJV)
- Cast iron with nodular graphite (GJS)

Today, cast iron and cast-iron alloys are used primarily in high-performance engines.

GJL (gray cast iron) is the most commonly used casting material, due to its good machinability, boundary lubrication properties that support lubrication, excellent thermal conductivity, and good noise-damping characteristics. Lamellar gray cast iron with perlitic basic microstructure can be manufactured with tensile strengths of up to approximately 350 N/mm². It is therefore a suitable material for cylinders, among other applications. To ensure wear resistance, phosphorus or carbide-forming elements are added, or the running surfaces are inductively hardened. Phosphorus forms hard steadite, which forms as a network if the phosphorus proportion is sufficiently high.

GJV has a greater load carrying capacity than GJL, but due to its greatly reduced sulfur content, it is much more difficult to machine. Because of its higher cost, GJV is currently used only in turbocharged diesel engines with special requirements profiles.

GJS has an even greater load-carrying capacity than GJV, but is more difficult to cast and less thermally conductive. It higher cost is another disadvantage.

| Description (Abbreviation old/new) | Unetched micrographs | Etched micrographs | Strength Examples |
|---|---|---|---|
| Cast iron with lamellar graphite (GG/GJL) |  Cast iron with lamellar graphite, unetched |  Etched GJL, perlitic microstructure, steadite network | 150–400 N/mm² <br> Cylinder liners, cylinder blocks, brake discs |
| Cast iron with vermicular graphite (GGV/GJV) |  Cast iron with vermicular graphite, unetched |  Vermicular graphite, etched | 300–500 N/mm² <br> High-performance cylinder blocks, turbochargers, manifolds |
| Cast iron with nodular graphite (GGG/GJS) |  Cast iron with nodular graphite, unetched |  Nodular graphite, etched, perlitic | 350–900 N/mm² <br> Piston rings, gears, crankshafts, machine components |

MAHLE Aftermarket GmbH
Pragstraße 26–46
70376 Stuttgart/Germany
Phone +49 711 501-0

www.mahle-aftermarket.com
www.mpulse.mahle.com

mahled-153/02.2021/EN