Introduction of engine block

Until recently, cast iron and aluminum alloys have been successfully used to manufacture most diesel and conventional gasoline-powered engine blocks.

However, with a greater emphasis on increasing the efficiency of the engine via weight reduction, there is a search for alternative alloys that are lighter than cast iron and aluminum alloys, while retaining the necessary strength to withstand the forces of an engine. In the late 1990s engine blocks made from plastic and other experimental materials were being used in prototype cars with the hope of developing more lightweight, efficient vehicles .

Also lately new manufacturing processes have been developed that have brought to light two new alloys suitable for use in an engine block, magnesium alloy AMC-SC1 and compacted graphite cast iron (CGI). Thus this project will cover, the functional requirements of the engine block, the processes used to manufacture the part, and the mechanical properties of the alloys.

INTRODUCTION:

Today's engines are an integral component of an automobile that are built in a number of configurations and are considerably more complex than early automotive engines.

The use of lighter and stronger engineering materials to manufacture various components of the engine has also had an impact allowing engineers to increase the power-to-weight of the engine, and thus the automobile. Since the engine block is also a relatively large component, it constitutes 20-25% of the total weight of an engine. Thus there is much interest in reducing the block’s weight.[Keay, Sue: “ Diet of Australian metal lightens cars and pollution,” Media release, 14 October

2002.]

Many early engine blocks were manufactured from cast iron alloys primarily due to its high strength and low cost. But, as engine designs became more complicated, the weight of the engine (and thus the vehicle) had increased. Thus the need to come up with lighter alloys that were as strong as cast irons arose. One such material that was being used as a substitute was aluminum alloys. Together, these two metals were used exclusively to fabricate engine blocks.

Lately , however, a new material process has made a magnesium alloy suitable for use in engines. The alloy, called AMC-SC1, weighs less than both cast iron and aluminum alloys and represents new possibilities in engine manufacturing. A new manufacturing process have made compacted graphite cast iron (CGI) a viable alternative to gray cast iron for the manufacture of diesel engine blocks. Like magnesium alloys, this material offers a higher strength and lower weight than gray cast iron.

Thus this section will cover materials used to manufacture engine blocks , component discussion, its functional requirements, and the materials used to manufacture the part. The mechanical properties of the individual alloys will be incorporated, along with the manufacturing processes used to fabricate the component.

DESCRIPTION OF THE PRODUCT:

WHAT IS AN ENGINE BLOCK? :

The engine block is vital structure of vehicles which run on internal combustion, providing the powerhouse for the vehicle. The engine block is termed a block because it is usually a solid cast, housing the cylinders and their components inside a cooled and lubricated crankcase . Common components found in an engine include pistons, camshafts, timing chains, rocker arms, and other various parts. When fully stripped of all components, the core of the engine can be seen: the cylinder block. The cylinder block (popularly known as the engine block) is the strongest component of an engine that provides much of the housing for the hundreds of parts found in a modern engine. The block is typically arranged in a “ V,” inline, or

horizontally-opposed (also referred to as flat) configuration and the number of cylinders range from either 3 to as much as 16. Figure 1 shows engine blocks with “ V” configuation.

opposed configurations.

Functional Requirements of a Cylinder Block:

Because engine blocks are a critical component of an engine, it must satisfy a number of functional requirements. These requirements include withstanding high cycle fatigue stresses, thermal strains, and aggressive wear conditions over the full life of the engine, housing internal moving parts and fluids, ease of service and maintenance.

REQUIRED MATERIAL PROPERTIES:

The one-dimensional era of engine design is finished. The current approach considers the loads acting at each point of the engine block. (Vollrath, 2003)

In order for an engine block to meet the above functional requirements, the engineering material(s) used to manufacture the the cylinder block material should have adequate strength and rigidity in compression, bending, and torsion. This is necessary to resist the gas pressure loads and also for the components, which convert the reciprocating motion of individual piston into a single rotary motion.

The cylinder-block material should

(a) be relatively cheap,

(b) readily produce castings with good impressions,

(c) be easily machined,

(d) be rigid and strong enough in both bending and torsion,

(e) have good abrasion resistance,

(f) have good corrosion resistance,

(h) have a high thermal conductivity,(to prevent failure under high temperatures).

(i) retain its strength at high operating temperatures, and

(J) have a relatively high thermal expansion, low density.(to resist expanding under high operating temperatures)

High strength is a particular concern in diesel engines, since compression ratios are normally 17. 0: 1 or higher compared to about 10. 0: 1 for conventional engines. , and thermal conductivity . Good machinability and castability of the metal alloy are also important factors in selecting the proper material, as the harder it is to machine the product, the higher the costs of manufacturing. In addition to the previously mentioned properties, the alloys must possess good vibration damping to absorb the vibrations of the moving parts.

METALS USED IN THE MANUFACTURE OF THE CYLINDER BLOCKS:

Based on the functional requirements of the cylinder block and the material properties required to meet the functional requirements, industries have used cast iron and aluminum alloys to manufacture the blocks.

EXISTING MATERIALS:

1)Cast iron alloys are used because of the combination of good mechanical properties, low cost, and availability.

2)Certain aluminum alloys combine the characteristics of iron alloys with low weight, thereby making the material more attractive to manufacturers who are seeking a competitive edge.

NEW MATERIALS:

3)Compacted graphite cast iron is lighter and stronger than gray cast iron, making the alloy a more attractive alternative to the latter in the production of cylinder blocks, particularly in diesel engines.

4)Magnesium alloys, which were previously unsuited for use as an engine block material, have the advantage of being the lightest of all the mentioned metals, yet still retains the required strength demanded by a block.

1)GRAY CAST IRON ALLOYS:

Gray cast iron alloy have been the dominant metal that was used to manufacture conventional gas-powered engine blocks. Though extensive use of aluminum alloys has minimized the popularity of this material, it still finds wide use in diesel-fueled blocks, where the internal stresses are much higher. The use of cast iron blocks has been wide spread due to its low cost and good formability. Generally types of gray cast iron of pearlite microstructure is used in the manufacturing of engine block.

Gray cast iron alloys typically composition:

A typical cast iron is a gray cast iron, which contains 2. 5-4 wt.% carbon, 1-3 wt.% silicon, 0. 2-1. 0 wt.% manganese, 0. 02-0. 25 wt.% sulfur, and 0. 02-1. 0 wt.% phosphorus [Anyalebechi, P. N.: " Essentials of Materials Science &Engineering," January 2005, p. 94.]. and the balance (93. 6%) iron. The carbon improves lubrication property of graphite, the silicon controls the formation of a laminated structure, called pearlite, which has good wear

resistance, and the manganese strengthens and toughens the iron structure. A common aluminium alloy composition is 11. 5% silicon, 0. 5% manganese, and 0. 4% magnesium, with the balance (87. 6%) aluminium. The high silicon content in this alloy reduces expansion but improves cast-ability, strength, and abrasion resistance, while the other two elements strengthen the aluminium structure. While this alloy provides a good corrosion resistance, it can absorb only moderate shock loads.

Types of cast iron used in engine block:

SAE grade G2500- used for small engine blocks.

SAE grade G3500-used for heavy and larger diesel engine blocks.

Also some ductile iron are also used in manufacturing engine blocks.

SAE AMS 5313C:

mechanical properties: [alloying: understanding the basics , by joseph R devis.]

Grade or class

Hardness HB(a)

Tensile strength min(b) MPa

Yield strength min(b)

MPa

Elongtion in 50 mm(2in),%(b)

Class A

190 max

414

310

15

Gray cast iron has excellent damping capacity, good wear and temperature resistance, is easily machinable, and is inexpensive to produce. However, gray cast irons are relatively weak and are prone to fracture and deformation.

Although cast iron meets most of these requirements, it has a low thermal conductivity and is comparatively heavier. Due to these limitations, light aluminium alloys have been used as alternative cylinder-block materials for petrol engines. Cylinder liners are optional with cast-iron blocks; but are more essential with the relatively soft light aluminum alloy blocks, as they cannot directly withstand wear resistance. Because of the lower strength of the aluminum alloys, the blocks are cast with thicker sections and additional support ribs, so that their weight becomes about half of the equivalent cast-iron blocks. Due to these problems, compacted graphite iron has recently begun to compete with gray cast iron as the choice material to produce diesel engine blocks.

COMPACTED GRAPHITE CAST IRON:

Compacted graphite cast iron (CGI), which was accidentally discovered while trying to

produce ductile cast iron, possesses higher tensile strength and elastic modulus than gray cast iron due to the compacted graphite found on the microstructure of CGI.

Figure 8 – CGI typical microstructure: 5% nodularity, 9% graphite, 265 particles/mm2.

3. CGI – a new combination of properties:

As shown in Fig. 8, the compacted graphite iron graphite particles appear as individual ‘ worm-shaped’ or vermicular particles. The particles are elongated and randomly oriented as in gray iron; however they are shorter and thicker, and have rounded edges. The compacted graphite morphology inhibits crack initiation and growth and is the source of the

improved mechanical properties, as compared to gray iron. Compacted graphite iron invariably includes some nodular (spheroidal) graphite particles. As the nodularity increases, the strength and stiffness also increase, but only at the expense of castability and thermal conductivity (Guesser et all, 2001). It is usual to set a limit of 20% nodularity for CGI specifications. Table 1 shows mechanical properties of CGI, with grades from 300 to 500 MPa.

In the case of cylinder blocks and heads, where castability, machinability and heat transfer are all of paramount importance, it is necessary to impose a more narrow specification. A typical specification for a CGI cylinder block or head can be

summarised as follows:

1) 0-20% nodularity, for optimal castability, machinability

and heat transfer

2) No free flake graphite, flake type graphite (as in grey

iron) causes local weakness

3) > 90% pearlite, to provide high strength and consistent

properties

4) <0. 02% titanium, for optimal machinability

This general specification will result in a minimum-measured tensile strength of 450 MPa in a 25 mm diameter test bar, and

will satisfy the ISO 16112 Compacted Graphite Iron standard for Grade GJV 450. The typical mechanical properties for this

CGI Grade, in comparison to conventional grey cast iron and aluminium are summarised in Table 1:

Mechanical and Physical Propertiesof CGI in comparison to conventional grey cast iron and aluminium at 20°C

Property

Units

GJV 450

GJL 250

GJL 300

A 390. 0

Ultimate Tensile Strength

MPa

450

250

300

275

Elastic Modulus

GPa

145

105

115

80

Elongation

%

1 to 2

0

0

1

Rotating-Bending Fatigue 20°C)

MPa

210

110

125

100

Rotating-Bending Fatigue (225°C)

MPa

205

100

120

35

Thermal Conductivity

W/m-K

36

46

39

130

Thermal Expansion

Î¼m-m-K

12

12

12

18

Density

g/cc

7. 1

7. 1

7. 1

2. 7

Brinnell Hardness

BHN 10-3000

215-255

190-225

215-225

110-150

The results allow the comparison between CGI and gray iron. It can be seen the increase on tensile strength, moving from gray iron to CGI. CGI also shows a higher elastic modulus, when compared to gray iron.

[- Mechanical properties of gray iron and CGI grades 400-450. 195-230 HB. Samples

taken from the castings (Guesser, 2003)].

Figure 10 – [Elastic modulus of gray iron and CGI grade 400. 12. 0L I6 cylinder block (Guesser,

2003).]

The results in Figure 10 were obtained from two sources: test bars and main bearings of a 12. 0L cylinder block. The increase in elastic modulus, from 100 GPa for gray iron to 150 GPa for CGI, results in slighter cylinder bore distortion as reported by Tholl et all (1996), therefore reducing oil consumption and emissions. Results of fatigue strength tests can be seen on figure 11, comparing gray iron grade 250 and CGI grade 450, samples from an I6 5. 9L diesel cylinder block. The fatigue limit for the gray iron is 62-79 MPa, depending on the carbon content, while for the CGI the fatigue limit is 175 MPa. The raise of fatigue strength allows the designer to reduce the cylinder block weight.

As a result of mechanical properties improvements, a design study conducted by AVL Austria (Sorger & Holland, 1999) has evaluated downsizing opportunities for a 1. 8 L diesel engine cylinder block, converting from gray iron to CGI. The benefits of this conversion included:

1)9% reduction in overall weight of the finished engine

2) 22% reduction in weight of machined cylinder block

3) 15% reduction in overall length of the finished engine

4) 5% reduction in both; height and width of the finished engine

Like gray cast iron, compacted graphite cast iron has good damping capacity and thermal

conductivity, but its difficulty to machine has limited the wide-scale use of CGI. A new

manufacturing process, however, has opened the way for larger applications of CGI. The

development of rotary insert tools has increased the life of the tools used to machine the metal,

thus allowing manufacturers to use CGI without worrying about purchasing new tools [Georgiou, George: " Iron engines may be in your future," Tooling & Production, September

2003, Vol. 69, issue 9, p. 26.].

MAGNESIUM ALLOYS:

Magnesium alloys have been used in engines before, but not for cylinder blocks. Rather. The main advantage of this alloy is that the material is much lighter than cast iron and aluminum alloys and has the same strength as cast iron and aluminum alloys[Lampman, Steven: “ Tuning Up the Metals in Auto Engines,” Advanced Materials &

Processes, May 1991, p. 17.][Anonymous, “ Magnesium alloy resists high temperature in engine blocks,” Advanced

Materials and Processes, August 2003, vol. 161, issue 8, p. 13.]. Material scientists and engineers were determined to exploit these characteristics of magnesium alloy and use it to fabricate engine blocks. There were a number of magnesium alloys available that met or exceeded the requirements demanded by manufacturers for an engine block, but insufficient material stability

at high temperatures hindered their actual use. Following are the two alloys which have been found suitable for mass production of engine blocks.

AMC-SC1:

In 2003 material scientists and engineers from the Cooperative Research Center for Cast Metals Manufacturing and the

Australian Magnesium Corporation presented their discovery of sand-cast AMC-SC1 magnesium alloy [Anonymous, “ Magnesium alloy resists high temperature in engine blocks,” Advanced

Materials and Processes, August 2003, vol. 161, issue 8, p. 13.]. This grade of magnesium alloy contains two rare earth elements, lanthanum and cerium, and was heat-treated with T6. This stabilizes the strength of the alloy at high engine operating temperatures, which is a necessary requirement for a cylinder block

material [16]. Bettles et al. had performed experiments to determine the yield and creep strengths of AMC-SC1 and their results are shown in Table 3 [Bettles, C. et al., “ AMC-SC1: A New Magnesium Alloy Suitable for Powertrain

Applications,” Society of Automotive Engineers, 2003, p. 2.]. From Table 3, the most significant point is that the yield strength of AMC-SC1 essentially stays the same at 177°C as it does at room temperature.

Table 3: Yield and creep strengths of magnesium AMC-SC1 at room temperature, 150°C, and

177°C [17].

Room temperature

24°C

150°C

177°C

Yield strength, MPa

120

116

117

Creep strength, MPa

—

120

98

This means that the material is able to tolerate a wide range of operating temperatures without a loss in strength. Other properties of the magnesium alloy 10 include good thermal conductivity, excellent machining and casting qualities, and excellent damping characteristics. To demonstrate the significant weight savings of magnesium alloy over cast iron and

aluminum alloy, consider BMW's inline-6 R6 (shown in Figure 4), which replaced the company's M54 aluminum engine. Its cylinder block is made of AMC-SC1 and is said to have decreased the weight of a comparably-built gray cast iron and aluminum alloy block by 57% and 24% [Jost, Kevin: " BMW builds better inline six," Automotive Engineering International, January

2005, pp. 20-32.]. So far, BMW is the only company to have used magnesium alloy cylinder blocks in production vehicles. But, with a significant weight advantage over the current alloys used today and negligible increase in cost, other manufacturers will begin to consider the use of AMC-SC1 and possibly other grades of magnesium alloys for engine blocks.

Figure 4: BMW’s 6-cylinder R6 powerplant uses a magnesium alloy AMC-SC1-fabricated

cylinder block [Jost, Kevin: “ BMW builds better inline six,” Automotive Engineering International, January

2005, pp. 20-32.].

PRODUCTION PROCESS: STANDARD CASTING WITH SOME MODIFICATIONS:

This alloy can be cast using a standard production process, with some modifications.

For a magnesium alloy engine to be economically viable, it is not merely the cost of

the alloy that is important. The casting process must also be commercially viable.

There are several modifications required if an existing casting line of cast iron or aluminum is to be converted to

one producing magnesium parts.

These can be summarised as follows:

- A new inhibitor in the sand cores to prevent reaction between the melt and the

sand.

- A redesign of the runner and gating system to ensure adequate filling (magnesium alloys have a low heat content).

- Preheating of the core package to 150°C.

- Modifications to the core package design to allow low pressure rather than gravity filling and feeding.

AM-HP2:

AM-HP2 – A High Pressure Diecasting Magnesium Alloy:

The AM-HP2 magnesium alloy has similar high-temperature strength to AM-SC1 and has been specially tailored for use in the high pressure diecasting process. Like AM-SC1, the light-weight alloy significantly increases fuel-efficiency, environmental sustainability and vehicle agility and is suitable for the powertrain components of vehicles, such as engines blocks etc.

Need for New alloy: AM-HP2

AM-HP2 has been specifically developed as a diecasting alloy for high temperature automotive powertrain applications, such as engine blocks, structural sumps and automatic transmission housings. The alloy is based upon the successful sand casting alloy, AM-SC1, with a modified composition to make it suitable for the high pressure die casting process.

Commercial Opportunities AM-HP2 Magnesium Alloy in the Auto industry:

High pressure diecasting is a highly productive process for mass production of light alloy components. While the casting integrity of sand casting and low pressure/gravity permanent mould castings is higher than high pressure diecasting, the latter technology is cheaper. Thus, this process is gaining popularity among auto manufacturers for casting of aluminium engine blocks. It is also the common process for powertrain components such as transmission housings. There is a strong demand in the automotive industry for a suitable high pressure diecasting magnesium alloy for high volume powertrain applications. AM-HP2 exhibits good diecastability and the required high temperature mechanical properties for engine components (including engine blocks) and automatic transmission housings. It has similar creep properties to alloy, AM-SC1.

Advantages of AM-HP2 Magnesium over Other Alloys:

A key advantage of AM-HP2 is that the alloy is more diecastable than competitor high temperature creep resistant magnesium alloys. Thus, the alloy can be more readily cast into complex shapes with fewer rejects and a wider operating window. The alloy also has better high temperature creep strength than its competitors and thus offers considerable advantage to engine designers seeking to obtain maximum performance for lowest weight and cost.

current status of AM-HP2 magnesium development:

Pilot scale diecasting trials and laboratory testing of mechanical properties have demonstrated the suitability of AM-HP2 for mass produced powertrain components.

PRODUCTION PROCESSES:

3. 2 – Casting Processes

There are two methods used to cast engine blocks for all materials: green sand molding or lost foam casting. The latter, pioneered by General Motors for their Saturn vehicles, have[11] become more popular due to its capability to produce near net shape components, provide tight tolerances for critical components, and reduce machine maintenance and cost [19]. Green sand molding, however, is still widely used in industry as material costs are low and most metals can

be cast by this method [Luther, Norris: " Metalcasting and Molding Processes," [Online], 22 March 2005-last visited,

Available: http://www. castingsoruce. com/tech_art_metalcasting. asp.].

3. 2. 1 – Green Sand Molding:

Green sand molding the common method to cast engine blocks. The term " green" denotes the presence of moisture in the molding sand .

Figure demonstrates the pattern used in sand casting.

The pattern mounted into the moulding box along with the runner and ingate system ready to produce a mould.

[http://www. dmdaustralia. com. au/block1. html]

From Figure 2, a combination of silica sand, clay, and water poured in one-half of the block pattern with a wood or metal frame. The mold is then compacted by squeezing or jolting, and the process is repeated for the other half of the mold. A core consisting of hardened sand is used for support.

Then, molten cast iron, aluminum, or magnesium alloy is poured into the combined molds and solidifies.

Once the latter part has been completed, the molds are removed, and the cylinder block is cleaned and inspected. Heat treatment of the block is then undertaken to improve the mechanical properties of the alloy for suitable use.

[7].

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LOST FOAM CASTING:

THE PROCESS:

Figure 6: Graphical description of the last 6 of 7 methods of the lost foam casting method [Anonymous, “ Aluminum Cylinder Block for General Motors Truck/SUV engines,” A Design

Study in Aluminum Casings, pp. 1-31.]

The lost foam casting process uses a expanded polystyrene replica of the part being cast.

1)The coated replica/pattern is placed in a flask and loose sand

is placed around the pattern and shaken into its voids.

2)Molten metal is then poured through a foam sprue, or

funnel, into the sand where the hot metal melts and displaces the foam of the pattern.

3)the metal cools in the shape of the part.

The basic steps of the lost

foam casting process are:

1) Pattern Molding – Bead Pre expansion and Conditioning, Tool Preheat, Pattern Molding, Pattern Aging

2)Pattern/Cluster Assembly

3)Pattern Coating and Drying

4)Sand Fill and Compaction Metal Casting and Cooling

5)Shakeout, Clean-up, and Finishing

Lost foam casting is a more reliable and efficient casting technique of the manufacture of engine blocks than green sand molding. The technique begins with the use of polystyrene beads placed in preexpanders for wet expansion to control bead size and density to produce four separate block moldings to be glued together to form the final mold [7, 19]. Next, the metal tool is preheated to remove any moisture and then filled with the beads. The tool is then heated via steam and placed in an autoclave, where it is subjected to high pressures in order to create the molds [7]. The tool is removed from the autoclave and immersed in water to finish the moldings. Precise control over the heating and cooling aspect ensures dimensionally accurate, smooth and strong molds [Anonymous, " Aluminum Cylinder Block for General Motors Truck/SUV engines," A Design

Study in Aluminum Casings, pp. 1-31.]. If the tool was not heated before the beads were injected, the results would be rough finishes in the molds with low-strength sections. If the tool and beads stay heated for an extended period of time, or is not cooled enough, the beads become overfused," which produces surface variations in the moldings. If the tool has been

inadequately cooled, the molds will contain variations in dimensions [Anonymous, " Aluminum Cylinder Block for General Motors Truck/SUV engines," A Design

Study in Aluminum Casings, pp. 1-31.]. Figure 3 shows the

final half stages of the lost foam casting method. . From Figure 3, once the individual molds are glued together, the assembly is placed in a vat with water-based ceramic liquid to prevent molten metal from destroying the mold, stiffen the assembly, and provide a smooth finish [Anonymous, " Aluminum Cylinder Block for General Motors Truck/SUV engines," A Design

Study in Aluminum Casings, pp. 1-31.]. The assembly can also be sprayed with the ceramic liquid, but is a time-consuming process. Next, the coated foam engine block is filled with sand,[13] compacted, and immersed in the molten metal alloy. Once cooled, sand is removed from the metal casting, cleaned, and undergoes heat treatment to increase the mechanical properties of the block. Finally, coolant and oil passages are machined into the block.

Advantages over conventional sand casting:

Unlike conventional sand casting, the lost foam process allows more complex and detailed passages and other features to be cast directly into the part. The lost foam process:

1) Forms complex internal passages and features without cores.

2) Reduces part mass with near net shape capability.

3) Eliminates parting lines.

4) Reduces machining operations and costs.

5)Provides for tight tolerances in critical areas and features.

Lost Foam Casting for Fine Features:

The lost foam casting process allows more complex and detailed passages and other features to be cast directly into the cylinder block.

1) In the cylinder block, oil galleries, crank case ventilation

channels, oil drain back passages, and coolant passages are cast

into the block.

2) These features would otherwise require drilling or external

plumbing (with a potential for leaks).

3)Lost Foam castings have tighter dimensional tolerances compared to sand castings, because variations caused by core shift and core variability are eliminated and there is much less tool wear over the production life. The direct result is a significant reduction in machining costs and infrastructure investment and fewer opportunities for errors in machining and assembly.

A comparison of green sand casting to lost foam casting shows a number of distinct advantages for lost foam:

Property

Green Sand Casting

Lost Foam Casting

Complex Internal

Features and Part

Consolidation

Complexity determined by sand core

limitations — geometry, strength, and

cost.

Extensive and complex internal features (as small as

0. 20″) available in lost foam, based on detail duplication and pattern assembly in foam.

Dimensional

Tolerances

+/- 0. 030″ is typical depending on part

size, complexity, and geometry

+/- 0. 005″-0. 010″ is typical depending on part size, complexity, and geometry.

Surface Finish

Capabilities

250-600 microinches typical. Depends

on grain fineness of sand.

60-250 microinches typical. Depends on bead size and ceramic coating grain fineness.

Feature Accuracy

Core movement and shift between mold

halves across the parting line limit

feature accuracy.

No cores or mold halves to shift and degrade feature

accuracy

Parting Line and

Draft Angles

Parting lines and draft angles are

necessary for molding.

No parting lines in the mold and minimal draft on tools.

Environmental

Costs

Sand recovery requires binder removal

and time consuming sand clean-up

Sand is binder free, so it can be easily and rapidly recovered a