Mg Showcase

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Z4 Roadster sports the R6 composite magnesium-alloy engine. All photos, Copyright © 2007 BMW AG.
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Magnesium Fosters Rebirth of an Automotive Engine

Advanced metals technology is the catalyst for breakthrough engine development at Bavarian Motor Works (BMW). Their engineers envisioned a lighter, more powerful and durable six-cylinder inline combustion engine and set out to create the world's first engine block made of Noranda's patented alloy AJ62 (Mg-Al-Sr). The new composite magnesium-aluminum alloy engine went from concept to production in less than four years, debuting on the production line at BMW's Landshut plant in June 2004.

The R6 magnesium-aluminum alloy engine is now the cornerstone of BMW's fleet of automobiles and sports activity vehicles. Magnesium's singular weight advantage sparked rapid development and testing of composite magnesium alloy technology, which allowed engineers to completely reinvent their *ultimate driving machines*. The engine's initial success with customers launched the R6 into production on a mass scale and is now produced in series 1, 3, 5, 6, 7, Z4, X3, and X5 BMW vehicles, selling more than 300,000 cars in 2006.

BMW's composite magnesium-aluminum alloy engine is the lightest 3.0 liter in-line six-cylinder gasoline engine in the world.

Recycling Magnesium Adds Sustainability to BMW's Success

"BMW's light metal foundry… recycles in house, and remelts ingot systems within its own melt shop, recycling 40 percent of its magnesium requirement."

BMW's light metal foundry at the Landshut plant recycles in-house and remelts ingot systems within its own melting shop, recycling 40 percent of its magnesium requirement (9,000 tons per year). Two external recycling partners work with the facility on a reuse plan in which the foundry gets the same quantity of material back from the recycler that they previously sent them, with BMW selling only the chips. The company is committed to ensuring that its plant and light metals foundry operations are both sustainable and environmentally responsible.

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"The most important aspect of choosing magnesium for this radically advanced engine concept is the significant weight reduction."

The most important aspect of choosing magnesium for this radically advanced engine concept is the significant weight reduction. BMW's goal was to achieve an engine capable of increased power output and higher torque, while still lowering fuel consumption and CO_2 emissions. The composite crankcase, featuring a magnesium alloy housing surrounding an aluminum insert, *is the lightest 3.0 liter inline six-cylinder gasoline engine in the world (161 kilograms).*

"The resulting magnesium-aluminum alloy engine is 24 percent lighter than a conventional aluminum engine…"

The second generation magnesium alloy engine features spray-guided lean burning precision injection, delivering simultaneous high-power performance and fuel efficiency.

The resulting magnesium-aluminum alloy crankcase is 24 percent lighter than a conventional aluminum engine, simultaneously increasing power performance *and* fuel efficiency. Design innovation combined with advanced metallurgy affords this engine the best power-to-weight ratio and lowest specific fuel consumption, requiring fewer parts and less engine assembly work– an achievement that is now the benchmark for an entire company striving to enhance the joy of driving, while also being a good environmental steward.

Julian Friedrich, head of Corporate Communications for BMW Landshut plant, says, "Of course, consciousness of fuel economy and carbon-dioxide emissions has clearly increased. Our buyers are interested in driving a high performance car that is also fuel efficient and environmentally compatible. From 1990 to 2005, we reduced the fuel consumption of our cars in Germany by 30 percent."

A magnesium alloy system and a high pressure die casting (HPDC) process were created in tandem with the engine's design development to accommodate large volume production. The BMW Group installed its own magnesium foundry in 2004, costing about 100 million Euros. Magnesium alloy components are then sent to engine assembly plants in Munich, Germany, and Steyr, Austria.

During production, specially designed aluminum insert on the toolset incorporates cylinder liners and coolant ducts for the magnesium-alloy engine.

"The foundry in Landshut is one of the most innovative and efficient light metal foundries in the world," says Friedrich. "The foundry consumes about 38,000 metric tons per year of magnesium and aluminum – 9,000 tons in magnesium alone and more than 1.5 million engine components are manufactured at the Landshut plant each year."

BMW foundry site process engineers collaborated closely with power train design engineers and materials engineering specialists to test high-temperature magnesium alloys from different suppliers to find the magnesium/aluminum alloy combination with the best casting and mechanical properties. Magnesium/aluminum alloy AJ62 was chosen for its unique attributes of thermal and mechanical strength, casting and corrosion behavior, and superior creep resistance.

The cylinder head of the six-cylinder engine with BMW's technically advanced VALVETRONIC system.

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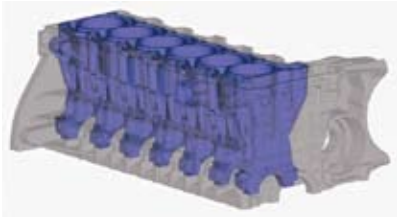
The light metal foundry's process engineers met the challenge of balancing magnesium and aluminum's different coefficients of specific thermal expansion, which required a breakthrough level of casting technology and process

At the fully-automated Landshut plant, the magnesium alloy crankcase is removed from the world's largest die-casting machine

reproducibility. Since conventional magnesium alloys are not suitable for the engine's cylinder liners due to insufficient stability and surface structure, aluminum inserts incorporating cylinder liners and coolant ducts are used in the engine block. As the magnesium housing shrinks around the aluminum insert, the thermally complex casting process ensures that both components heat up and cool down at precisely the right time during production.

The fully automated crankcase manufacturing process uses the world's largest die-casting machines. The two-piece mold, weighing nearly 60 tons, closes over the aluminum insert with 4,000 tons of hydraulic force. Liquid magnesium alloy (at 700°C) is then poured into the mold, maintaining a 970 bar pressure within the cavities and solidifying within ten seconds. After 20 seconds cooling time the metals are firmly bonded and the crankcase is robotically removed. Next the crankcase undergoes heat treatment, and further machining and finishing processes are completed.

"The engine bedplate's magnesium construction results in much higher torsional stiffness, providing greater fatigue strength, which supports the R6's top speed of 7,000 rpm."



Crankcase and bedplate are joined under tremendous pressure. Coolant water flows inside the aluminum cylinder inserts, never contacting the engine's magnesium alloy shell.

The engine bedplate's magnesium construction results in much higher torsional stiffness, providing greater fatigue strength, which supports the R6's top speed of 7,000 rpm. The magnesium crankcase and bedplate are tightly joined under high pressure with liquid sealant and bolted together, providing reduced vibration and enhanced acoustics. To complete the lightweight requirements, the R6 incorporates a magnesium cylinder head cover. The magnesium alloy engine shell never comes into direct contact with coolant water, since the water only flows inside the aluminum cylinder inserts.

Magnesium alloy engine cross-section view shows Valvetronic® variable intake system, magnesium alloy crankcase, bedplate, and cylinder head covers.

Another key factor in the composite magnesium-aluminum alloy engine's success is its pairing with BMW's technically advanced Valvetronic® system, which replaces a traditional engine throttle with variable intake valves. The engine's "breathing" is controlled by continuously varying the valves' lift height to regulate intake for more responsive power and improved performance, realizing an additional 12 percent fuel savings and lower emissions.

The R6 composite magnesium-aluminum alloy crankcase has earned the International Magnesium Association's Award of Excellence and is an engineering powerhouse driving BMW vehicles into the future. ❖

Fast Facts: Magnesium Alloy Engine

- Magnesium alloy engine was produced in 300,000 BMW vehicles in 2006
- Magnesium alloy crankcase is 24 percent lighter than conventional aluminum engine
- Engine achieves increased power output and higher torque
- Environmental benefits are reduced fuel consumption and CO_2 emissions
- R6 is lightest 3.0 liter inline six-cylinder gasoline engine in the world
- Magnesium alloy engine block and bedplate with aluminum cylinder inserts
- BMW foundry recycles 40 percent of its magnesium (9,000 tons per year)
- R6 composite magnesium-aluminum alloy crankcase received the International Magnesium Association's Award of Excellence

The R6 Composite Magnesium-Aluminum alloy engine is the mainstay of BMW's vehicle fleet.

To learn more about the benefits of designing products with magnesium, contact the
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