HIGH-PERFORMANCE ALUMINUM TECHNOLOGY

Lightweight Aluminum in Powder Metallurgy
THE MARKET’S DRIVE TOWARD LIGHTWEIGHT TECHNOLOGY

Market Drivers

- CO₂ emissions and fuel economy standards are mandating vehicle mass reduction
- Internal combustion engines and hybrid electric vehicle efficiency hinges on smaller engine size, increased transmission speed
- Reduction in mass reduces energy use for all forms of energy: ICE, Hybrid, and Electric

GKN Solutions

- GKN’s lightweight technology minimizes component mass without compromising performance
- GKN’s advanced Powder Metallurgy (PM) technology produces high-strength, net-shape parts geared toward ICE, hybrid and vehicle electrification
- GKN is the leader in PM technology and develops lightweight, high-performance Aluminum materials and products

Passenger car CO₂ emissions and fuel consumption, normalized to NEDC

Graph/The International Council in Clean Transportation
COMBINING EFFICIENT PROCESSING WITH ADVANCED LIGHTWEIGHT MATERIALS

Why Powder Metallurgy?
- Unrivaled Design Freedom
  - Unique part geometries
  - Simplified product design without compromised functionality
  - High material utilization greater than 90 percent
  - Rapid prototype development, scalable to high-volume production

Why GKN?
- Aluminum Metal Matrix Composite (Al MMC) Technology
  - Hard ceramic, uniformly distributed within tough Al-alloy matrix
  - Improved static and dynamic performance over conventional Al-alloys
  - Readily forgeable, significantly increasing mechanical performance
- Novel Al-Alloy with High Thermal Conductivity (TC2000 series)
  - Versatile material for thermal management applications

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Net shape</th>
<th>Efficiency</th>
<th>Inertia</th>
<th>Thermal</th>
<th>Mass</th>
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<tr>
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A recognized green technology
GKN’s ALUMINUM MMC

**Specific Strength**

- Higher strength-to-weight ratio, allowing for mass reduction and improved vehicle efficiency
- Forging specific strength exceeds steel PM alloys and forgings

**Wear Resistance**

- Superior resistance to sliding wear for use in hydraulic applications
- Minimized oil contamination (no abrasive Si particles), improved pump efficiency
- CTE match with aluminum housing improves overall pump efficiency

**Materials**

- Steel Forgings
- Steel PM Distalloys
- Titanium Forgings
- Aerospace Al MMCs
- GKN’s Al Forged MMC
- GKN’s Al PM MMC
- Al Castings

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Strength Tensile [(MPa)/(g/cm³)]</th>
<th>Mass Change of Ring (g)</th>
</tr>
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<tbody>
<tr>
<td>Steel Forgings</td>
<td>127</td>
<td>0.0214</td>
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<td>Steel PM Distalloys</td>
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<td>Titanium Forgings</td>
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<td>Aerospace Al MMCs</td>
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<tr>
<td>GKN’s Al Forged MMC</td>
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<td>0.0001</td>
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<tr>
<td>GKN’s Al PM MMC</td>
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<tr>
<td>Al Castings</td>
<td>87</td>
<td></td>
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</table>

**ASTM G77 – Block-on-Ring Wear Test**

- Increasing wear resistance
- Wear Scar Width (mm)
- Mass Change of Ring (g)
MATERIALS – GKN’S ALUMINUM TC2000 SERIES

> **Thermal Conductivity**

GKN’s TC2000 is the PM counterpart to commercially pure, wrought aluminum. TC2000 outperforms conventional extrusions and castings by limiting solute impurities within the aluminum matrix.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity (W/m-K)</th>
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<tbody>
<tr>
<td>Cast Al A380</td>
<td>96</td>
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<tr>
<td>Al 6061</td>
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<td>Al 6063</td>
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<td>Al PM TC2000</td>
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<td>Pure Aluminum</td>
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> **Qualitative Benefits**

- **Formability**: Unique, net-shape geometries with excellent tolerance control without costly machining.
- **Manufacturability**: High production volumes with reliable performance.
- **Green**: Minimal material scrap and completely recyclable material, minimizing environmental impact.
- **Design**: GKN engineers use modeling and simulation to ensure optimized designs, meeting customer requirements.
GKN Powder Metallurgy produces over 30 million engine camshaft caps per year, designed to exceed unique customer requirements. Several material options allow for design flexibility to optimize geometric precision, strength, toughness, wear resistance and/or cost.

- GKN’s PM netshape design only requires customer line bore
- High wear and fatigue resistance (with optional MMC material)
- Unique Z-loc, for dowel elimination
Planetary Reaction Carrier

This MPIF award-winning Planetary Reaction Carrier is the first commercial use of powder metal Aluminum MMC material for a carrier application. The technology won the 2018 Grand Prize in the MPIF Design Excellence Awards.

- Introduction of aluminum reduced the mass of the carrier application by 1 kg
- High wear resistance and lower inertial mass
- Maintains strength and fatigue at operating temperature of 150 degrees Celsius
- Industry-winning dimensional precision
Forged Products

Tailored preform design allows for highly controllable plastic flow.

Near-net shape, and economical process eliminates subsequent working operations.

Fatigue properties exceed wrought forged Aluminum.

GKN is in production development of Aluminum forged products:

- Tailored preform design allows for highly controllable plastic flow.
- Near-net shape, and economical process eliminates subsequent working operations.
- Fatigue properties exceed wrought forged Aluminum.

**Bending Fatigue Strength**

- **GKN’s 2618 MMC**
- **Wrought 2618**

**Graph:**

- Y-axis: Bending Stress (MPa)
- X-axis: Number of cycles

**Data Points:**

- 400
- 350
- 300
- 250
- 200
- 150
- 1E+03, 1E+04, 1E+05, 1E+06, 1E+07, 1E+08

**Images:**

- Conventional Forged Material
- GKN’s Forged MMC Material
Lightweight Applications

Heat Sink

GKN’s heat sink was developed to replace die cast components for a car radio cooling application.

- Unique tower and three section sizes, not practical for casting or extrusion
- Higher thermal conductivity, requiring less thermal mass
- No machining required, providing cost savings
- High ductility, reducing risk of cracking during mechanical attachment
ALUMINUM TECHNOLOGY

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