Powder Metal Magic

Design Innovations in PM Applications

Matthew Jaster, Associate Editor

Capstan Atlantic, located in Wrentham, Massachusetts, produces powder metal gears, sprockets and complex structural components. The company has provided unique powder metal products in a variety of industries including automotive, business machines, appliances, lawn and garden equipment and recreational vehicles. The recent resurgence of the automotive industry has played a large role in increasing opportunities in powder metal, particularly in areas like suspension, powertrain, steering column and electronic power steering (EPS). Richard Slattery, vice president of engineering at Capstan Atlantic, recently discussed some of the latest powder metal gear designs that are more cost effective compared to their cut steel alternatives.

Automotive Application

A helical/spur combination gear—where all gear data is relative to the journal diameters, rather than an inside diameter—was utilized for a power liftgate application. The elemental gear data is very precise to enable quiet gear performance as NVH (noise, vibration and harshness) thresholds are very sensitive to the end user. In order to function properly, the gear must run quietly. The part is compacted using two lower and upper punches, coupled with a proprietary helical bearing system to allow punches to spin freely under 45 tsi of pressure. (*Ed's note: See sidebar page 57 for more information*). A custom designed robotic material handling system is used to remove parts from the press and place them in sinter carriers. The pinion and gear have very precise elemental gear tolerances.

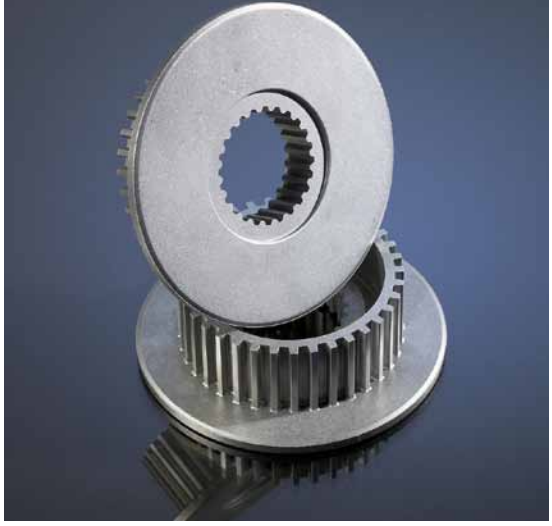
The significant process control challenge is that all the gear data is measured relative to the central axis of the part as established by the two opposing journal diameters. This presents challenging tool setup requirements as well as special fixturing for part measurement. The material is an FC 0208-50 (copper steel) with a nominal density of 6.85 g/cm^3 and a typical hardness of HRB 75, a yield strength of 55,000 psi and a tensile strength of 65,000 psi.

"This near-net-shape process is highly cost competitive versus other metalworking/gear manufacturing processes associated with this level of precision," Slattery says. "The part offers precise elemental gear tolerances for system noise reduction, without an inside diameter as a datum."

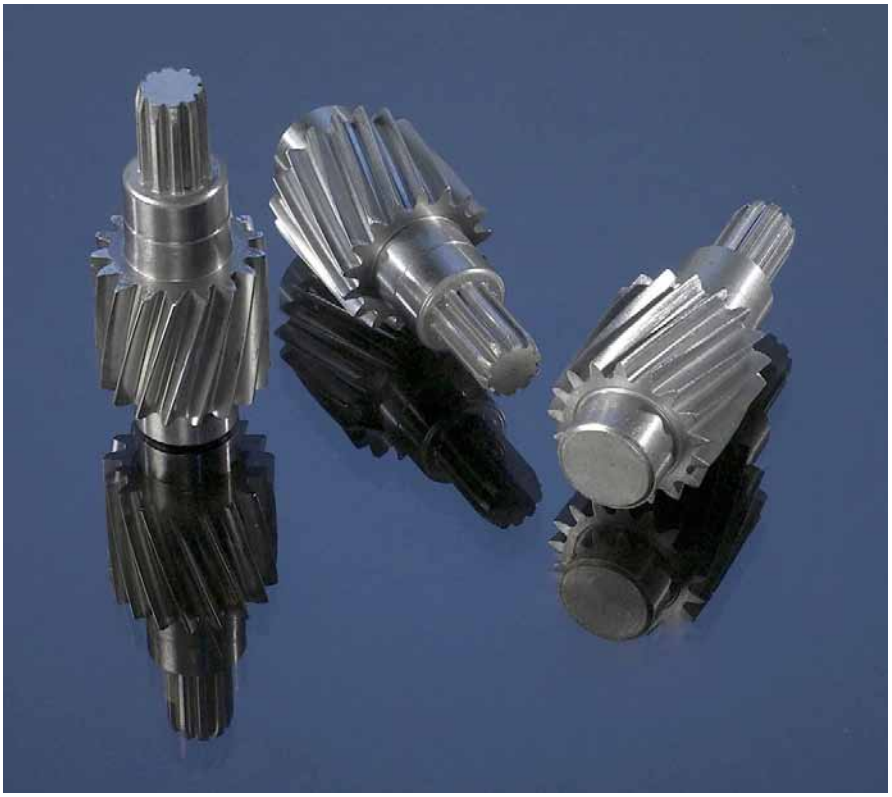
Lawn and Garden Application

A high precision, copper infiltrated, helical gear was needed for a two-cylinder engine application in the lawn and garden market. "This copper infiltrated helical crankshaft gear is compacted with a custom geometry to allow for subsequent gear tooth modification for high strength and minimum noise," Slattery says.

The gear offers a 25.5 degree helix angle, a custom involute profile that includes tip relief and a "mirror like" surface finish on the tooth flanks. The teeth have a maximum helix error



A net-shaped PM clutch hub combines multi-level technology, an innovative material system and a unique PM processing method (courtesy of Capstan Atlantic).



This helical/spur combination gear is utilized in a power liftgate actuator application (courtesy of Capstan Atlantic).

(lead) of 15 microns and a profile error of less than 30 microns. Additionally, this gear has an accurately machined inside diameter (24 microns total tolerance) and locating face, enabling precise assembly.

The gear requires a high level of tool geometry control along with minimum weight and sectional density variation at a compact and very consistent sinter temperature profile. The inside diameter is then precision machined and the teeth are rolled for densification and final qualification of the gear geometry. The material is an FX 1008-50 (copper infiltrated steel) at a 7.3 g/cm^3 minimum density and apparent hardness of RB 90. The elongation exceeds three percent and the impact strength exceeds 15J (10 ft-lbs). This elongation enables very high press fit interference on the mating crankshaft to eliminate the potential of gear slippage in service. The tensile strength of this material is > 600 MPa (90,000 psi).

This gear's as-sintered, near-net shape and its physical strength, along with precise dimensional control, replace a far more expensive wrought

steel alternative, offering a 35 percent cost reduction. "This gear has successfully passed all levels of endurance testing in this two-cylinder industrial engine application," Slattery says. "It's economically attractive, highly precise and costs almost fifty percent less than the cut steel alternative."

Industrial Application

A net-shaped PM clutch hub replaces a machined alternative that is more expensive. It combines multi-level technology, an innovative material system and a unique PM processing method. The part is compacted using four lower and a stepped single upper punch, coupled with an enhanced powder feed system to facilitate equalized local densities. Additional proprietary tool material and treatment systems are used to enable long, thin punches to withstand extreme tonnage. This is a complex, multi-level, higher dense component, capable of withstanding very high torque loads in service. The part is provided net shape, in the as-sintered/shot peened condition, replacing a previously machined version.

"The functionality of this hub requires very close relationships between the five diameters," Slattery says. "The tooth run-out to the internal spline is less than 100 microns (0.1 mm)."

The process control of the part is the consistent dimensional change for all levels through the sintering operation. This control is maintained by achieving sectional density variation within 0.05 g/cm^3 at the compaction step in the process. The material is a hybrid Fe/Mo/Cu/C alloy with very good yield strength and as-sintered tensile properties. The flange of this component is subjected to repetitive bending fatigue in service. Therefore, the ability to achieve the required strength, as well as the bending fatigue resistance, is the key to the field success of this component. "Simply put, this PM part offers precision, economic value and strength," Slattery adds.

Appliance Application

A complex, off-center-loaded PM rack has multiple lower levels, one of which is formed on the core rod platen and a dual upper punch system. Special robotic automation is required to remove the part from the lower tooling, flip it 180 degrees and place it on a special conveying system. "This is a seven level part requiring six punches. The rack system incorporates a progressive variable tooth space to compensate for system tooth engagement variation in service. The U slot density is controlled through off standard power distribution by the dual upper punches," Slattery says.

He continues, "This rack's as-sintered, near-net shape and its physical strength along with precise dimensional control, replace a far more expensive die cast alternative (a 38 percent cost reduction)."

The engineering properties include a highly controlled rack tooth profile and spacing characteristics. Perpendicularity of U slot to opposing locating surface is critical along with the flatness of the locating surface. This part requires a high level

of tooth geometry control along with minimum weight and sectional density variation at compact and a very consistent sinter temperature profile. Sinter distortion cannot be tolerated due to required component flatness. Specially engineered sinter fixturing assists in achieving this flatness, typically within 0.075 mm.

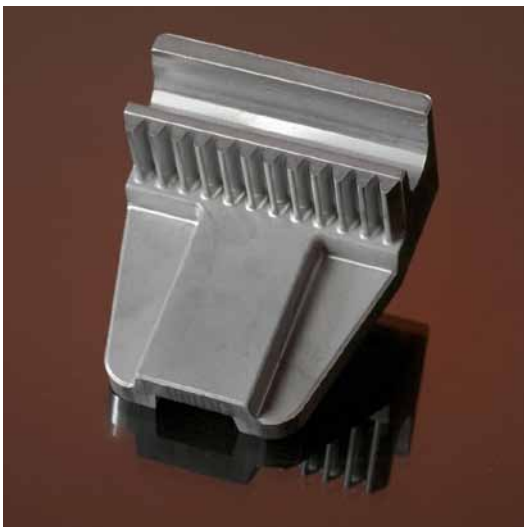
The material is an FC0205 with density in the rack, flange and U slot region at 6.8 g/cm^3. The sectional density is kept equal within 0.08 g/cm^3. This part has a minimum yield strength of 43,000 psi and typical tensile strength of 55,000 tsi, with a hardness of HRB 65.

"The rack has successfully passed bench and in-service life testing in this industrial washing machine application," Slattery says. "This rack along with the mating gear is what agitates the drum in these machines. The die cast alternative to this PM system is far more expensive due to the extensive machining required."

All of these examples illustrate the highly dense, high performance and improved dimensional precision found in PM gears. This has certainly helped powder metals gain significant growth within the gear industry and will continue to do so in the future.

For more information:

Capstan Atlantic
10 Cushing Drive
Wrentham, MA 02093
Phone: (508) 384-3100
www.capstanatlantic.com



This part requires a high level of tooth geometry control along with minimum weight and sectional density variation at compact and a very consistent sinter temperature profile (courtesy of Capstan Atlantic).

New PM Designs Highlight PowderMet2012

The 2012 Powder Metallurgy Design Excellence Awards (presented during the 2012 International Conference on Powder Metallurgy & Particulate Materials in Nashville) exemplify PM's special engineering benefits including net shape, precision, innovative fabrication methods, production efficiency, energy and materials savings, and manufacturing cost reduction. These advantages continue to stir designers to choose PM for critical applications in auto engines and transmissions, electronics, medical devices, agricultural equipment, consumer products, military equipment and emergency applications.

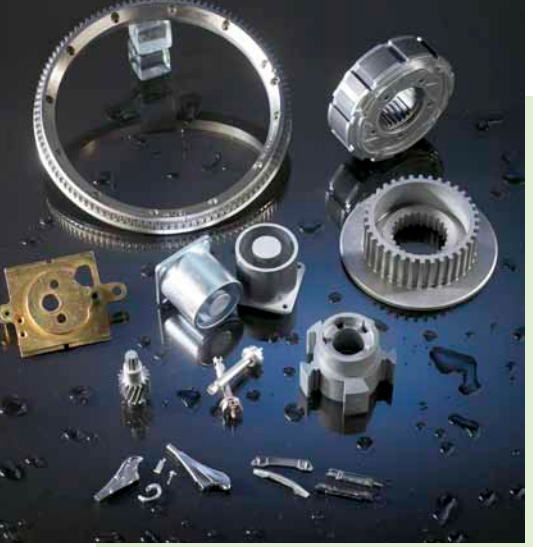
GKN Sinter Metals (located in Auburn Hills, Michigan) won the grand prize in the automotive engine category for a VVT rotor adapter assembly consisting of a PM steel rotor and adapter. The parts are joined by an adhesive, which joins them during machining cross holes and other features on the inside diameter, and seals the joint between them. GKN also won the grand prize in the automotive transmission category for a unitized one-way clutch (OWC) module made for the Chrysler Group. The module has four PM steel parts (powder-forged race and cam, and two pressed and sintered retainer plates) as well as 22 additional parts (clips, springs and roller elements).

Capstan Atlantic (located in Wrentham, Massachusetts) was awarded the grand prize in the automotive chassis category for a complex PM steel two-stage helical gear and spur pinion used in a power lift gate actuator. The precise elemental gear data tolerances enable quiet gear performance and decreasing noise, vibration and harshness.

FMS Corporation (located in Minneapolis, Minnesota) won the grand prize in the lawn and garden/off-highway category for a PM steel race gear used in the OnTrac2 GPS-assisted steering system made for Novariant Corporation in California. The system positions agricultural planting and harvesting equipment to more accurately perform tillage, spraying and spreading as well as reducing skips and overlaps, thus reducing fuel consumption.

In the hardware/appliances category, ASCO Sintering (located in Commerce, California) won the grand prize for a copper-infiltrated PM steel inside deadbolt chassis for a commercial electronic lock system. Maintaining the density between the hub and flange is especially critical in this application. The part has two PM posts manufactured and installed while maintaining true position and squareness.

FloMet LLC (located in Deland, Florida) won the grand prize in the aerospace/military category for a very complex 17-4 PH stainless steel rotor made by metal injection molding (MIM) and used in a hand-emplaced munitions device. The intricate design



Foreground: Medical introducer parts and eyeglass bridges. Second row: Helical gear and pinion, rotor, and VVT adapter. Third row: Deadbolt chassis, coil housing, and clutch hub. Back row: Gear-race and one-way clutch module (photo courtesy of MPIF).

is demonstrated by its four holes on two perpendicular planes, two-angled slots with square corners, and numerous internal and external radii, flats, slots and cutouts.

The medical/dental grand prize was awarded to Parmatech Corporation (located in Petaluma, California) for a mechanical introducer device used in minimally invasive OB/GYN surgery. The device contains five 17-4 PH stainless steel MIM parts, right and left cover, curved needle, curved needle linkage and center linkage. The covers have a complex 3-D geometry incorporating assembly pins and slots for moving the internal parts that require smooth action for suturing.

The electrical/electronic components category was won by Capstan California (located in Carson, California) for a soft magnetic PM alloy coil housing used in a magnetic door closer for emergency/fire protection applications. The PM design replaced a three-piece assembly and features the locations of drafts, radii and chamfers, as well as redefining tolerances for a near-net shape part.

Capstan Atlantic won the grand prize in the industrial motors/controls and hydraulics category for a PM steel alloy power take-off clutch. The part is designed to withstand very high torque levels in service, and the flange is strong enough to resist repetitive bending fatigue.

Smith Metal Products (located in Lindstrom, Minnesota) won the grand prize in the consumer market category for a 17-4 PH stainless steel MIM top and bottom of an eyeglass-frame bridge made for Superfocus LLC. Featuring very thin walls, the parts form the bridge section over the nose, which also houses an actuator for changing the magnification levels of the glasses.

Companies that accepted awards of distinction include SolidMicron Technologies (located in Singapore), Burgess Norton Mfg. Co. (located in Geneva, Illinois), PMG Group (located in Spain), ACL Bearing Company (located in Australia), Porite Taiwan Co. (located in Taiwan), Capstan Atlantic, Megamet Solid Metals, (Earth City, Missouri), Capstan California, Advanced Materials Technologies (located in Singapore) and Smith Metal Products.

PM Today and Tomorrow

In all materials, process and market sectors, the North American PM industry has built on the growth momentum begun last year, according to Matthew Bulger, president, MPIF.

Traditional press-and-sinter PM, metal injection molding (MIM), hot isostatic pressing (HIP), and other specialty PM technologies are thriving. PM is an interconnected technology that innovates and grows by leveraging its different sectors. Looking back at the past two years clearly suggests that the industry's recovery is sustainable. Iron powder shipments soared in 2010 after a terrible previous year. Total iron powder shipments grew modestly in 2011 to 363,831 short tons, a three percent increase. This increase was also achieved despite the shutdown of a major powder supplier's main plant for two months. Shipments of North American metal injection molding (MIM)-grade powders, including imports, jumped nearly 40 percent in 2011. The MIM process continued to garner greater acceptance in the materials marketplace. Some interesting R&D programs include developing MIM ultrasonic dentalscaler tips and endodontic tips, and titanium and cobalt–chromium alloys for medical-implant applications. The HIP business has also experienced robust growth in 2011 due to a general surge in manufacturing, and gains in the oil-and-gas, tool-steel, and aerospace markets. The HIPing of MIM parts continues to be a growing market.

Bulger noted that 2012 began on a very positive note, with rising confidence levels. First-quarter shipments of metal powders were up, as were volumes of PM parts and MIM parts. U.S. light-vehicle sales are expected to top 14 million units, up substantially from the 12.8 million units sold in 2011. Iron powder shipments through April this year rose by 11.25 percent to 134,925 short tons. Copper and copper-base and tin powder shipments have remained stable.

One of the key issues facing the entire industry is the serious need for experienced production workers and PM engineering professionals. Industry-wide employee reductions during 2008–09 have not been easy to reverse as the industry has rebounded. Another issue is capacity constraints: will the industry be ready to meet rising demands, particularly driven by the automotive industry, in the next several years? As was the case with staffs, rationalization moves during the same 2008–09 period included several plant closings and the scrapping of older equipment. Because it can take upwards of 10 to 12 months to build a high-end press and put it into production, Bulger cautioned, the equipment investment bandwagon must begin rolling sooner rather than later. Within the automotive sector, PM is approaching a saturation point in auto-engine content with existing technology. The average auto engine now contains up to 50 PM parts weighing more than 18 pounds, including connecting rods, bearing caps, valve-seat inserts, and VVT parts. With the average North America–built engine containing up to 170 individual parts, PM parts currently represent about 30 percent of the content. Potential growth appears more likely in transfer-case and transmission applications. For more information, visit *www.mpif.org*.