A Growth Industry Vital to Many Products

**Powder Metallurgy's Scientific and Industrial Importance:**

- A cost-effective method of forming precision net-shape metal components that allows for more efficiently designed consumer and industrial products.
- The source of high performance and advanced particulate materials and alloys such as superalloys, tool steels, PM aluminum alloys, dispersion strengthened metals, thermal spray materials, intermetallics and metal matrix composites.
- The leading edge of new manufacturing processes for improved product quality and productivity.
- Increases raw materials utilization through recycling and elimination of costly secondary machining through net and near-net shape design.
- Improves productivity by eliminating manufacturing.
- Delivers precision and special properties such as self-lubrication and controlled filtration.
- Only way of forming vital metals such as tungsten carbide, dispersion-strengthened materials, high speed tool steels, superalloys and self-lubricating bearings.
- Sustainable—saves natural resources through recycling and conservation of critical raw materials.
- Strategically important to products such as automobile engines and transmissions, aircraft turbine engines, riding lawn mowers, surgical instruments, power tools, oil/gas well drilling equipment and off-road tractors.

**History:**

Powder metallurgy was practiced long before ancient artisans learned to melt and cast iron. Egyptians made iron tools using PM techniques from at least 3000 B.C. Ancient Inca Indians made jewelry and artifacts from precious metal powders. The first modern PM product was the tungsten filament for electric light bulbs developed in the early 1900s. This was followed by tungsten carbide cutting tool materials and self-lubricating bearings in the 1930s; automobile parts in the ‘60s and ’70s; aircraft turbine engine parts, powder forged (PF) connecting rods, and metal injection molding (MIM) in the ‘80s, warm compacting in the ‘90s, nanotechnology and the acceptance of metal 3D printing/additive manufacturing (AM) in the new century.

**Industry:**

The PM parts and products industry in North America has estimated sales of $7 billion. It is comprised of companies that make conventional PM parts and products from iron, copper-base-powders and stainless steel; and companies that make specialty PM products such as superalloys, porous products, friction materials, strip for electronic applications, high strength permanent magnets, magnetic powder cores and ferrites, tungsten carbide cutting tools and wear parts, metal injection molding (MIM) parts, metal additive manufacturing (AM) parts, and tool steels—all from metal powders. PM is international in scope with growing industries in all of the major industrialized countries. Annual worldwide metal powder production exceeds 700,000 tons.

**Raw Materials:**

The most common metals available in powder form are iron and steel, tin, nickel, copper, aluminum and titanium, as well as refractory metals such as tungsten, molybdenum and tantalum. Alloys such as bronze, brass, stainless steel and nickel cobalt superalloys are also available in powder form.

Powder particles are specific in shape and size ranging from 0.1 to 1,000 micrometers. Particles are similar in size to the diameter of a human hair (25 to 200 micrometers). They are not merely ground-chips or scraps of metal. Major methods for making metal powders are atomization of molten metal, reduction of oxides, electrolysis and chemical reduction.

### North American Metal Powder Shipments

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron &amp; Steel</td>
<td>433,203</td>
<td>388,351</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>8,750 (E)</td>
<td>7,960 (E)</td>
</tr>
<tr>
<td>Copper &amp; Copper Base/Tin*</td>
<td>18,500 (E)</td>
<td>16,900 (E)</td>
</tr>
<tr>
<td>Aluminum</td>
<td>33,660 (E)</td>
<td>26,448 (E)</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>820 (R)</td>
<td>550 (E)</td>
</tr>
<tr>
<td>Tungsten</td>
<td>1,750 (E)</td>
<td>1,689 (E)</td>
</tr>
<tr>
<td>Tungsten Carbide</td>
<td>8,590 (E)</td>
<td>7,919 (E)</td>
</tr>
<tr>
<td>Nickel</td>
<td>6,100 (E)</td>
<td>5,500 (E)</td>
</tr>
</tbody>
</table>

(E) estimate (R) revised 511,373 455,317

*PM parts only short tons short tons
Trends and New Developments:

- Improved manufacturing processes such as cold or hot isostatic pressing (CIP/HIP), powder forging (PF), metal injection molding (MIM), metal additive manufacturing (AM), and direct powder rolling through increased scientific investigation of PM technology by government, academic and industrial R&D programs.
- Fully dense PM products for improved strength properties and quality in automobiles, diesel and turbine engines, aircraft parts and industrial cutting and forming tools.
- Commercialization of technologies such as metal injection molding (MIM), metal additive manufacturing (AM), PM forging, high temperature vacuum sintering, warm compacting and both cold and hot isostatic pressing.
- The use of powder forged (PF) connecting rods; PM composite camshafts; main bearing caps; and stainless steel ABS sensor rings and exhaust system flanges in automobiles.
- New submicron and nanophase powders for cutting tools and other specialized applications.

Applications:

PM parts are used in a variety of end products such as lock hardware, garden tractors, snowmobiles, automobile engines and transmissions, auto brake and steering systems, washing machines, power tools and hardware, sporting arms, copiers and postage meters, off-road equipment, hunting knives, hydraulic assemblies, x-ray shielding, oil and gas drilling wellhead components, fishing rods and wrist watches. Canadian nickels are made from strip rolled from pure nickel powder.

The typical U.S. light duty vehicle contains about 39 pounds of PM parts. Pickup trucks average about 70 pounds of PM parts, and range from 60 pounds to 95 pounds depending on the number of cylinders and whether it is 2WD, 4WD, or AWD. The typical mid-size SUV/CUV averages 45 pounds of PM parts. And, the typical U.S. passenger sedan averages 25 pounds of PM parts. More than an estimated 1.5 billion PM hot forged connecting rods have been made for light duty vehicles produced in the U.S., Europe and Japan.

Commercial aircraft engines contain 1,500-4,400 pounds of PM superalloy extruded forgings per engine.

Iron powder is used as a carrier for toner in electrostatic copying machines. Americans consume more than two million pounds of iron powder annually in iron enriched cereals and bread. Iron powder is also used in hand warmers and waterproof cements.

Copper powder is used in anti-fouling paints for boat hulls and in metallic pigmented inks for packaging and printing.

Aluminum powder is used in solid fuels for rockets such as the booster rockets for the space shuttle program.

Process:

The basic conventional PM process uses pressure and heat to form precision metal parts and shapes. Powder is compacted (at room temperature) in a rigid precision die at up to 50 tons per square inch into an engineered shape like a gear. Think of 50 compact cars stacked vertically and you have the pressure it takes to press the powder. After part compaction and ejection from the die, the part is fed slowly through a special controlled atmosphere furnace to bond the particles together. They are metallurgically fused without melting, a phenomenon called “sintering”.

Other processes are also used to consolidate powders into finished shapes such as cold or hot isostatic pressing (CIP/ HIP), powder forging (PF), metal injection molding (MIM), direct powder rolling, gravity sintering, and metal additive manufacturing (AM). One of these cutting-edge technologies, metal AM, builds parts layer-by-layer without the use of a mold or die, by sintering or welding each individual particle of powder.

In contrast to other metal forming techniques, PM parts are shaped directly from powders while castings are formed from metal that must be melted, and wrought parts are shaped by deformation of hot or cold metal, or by machining.

Metal Powder Industries Federation (MPIF):

Founded in 1944, MPIF is the trade association for the international metal powder producing and consuming industries. Members make metal powders, advanced particulate materials, process equipment and PM parts and products.

MPIF is comprised of the following PM trade associations:

- Powder Metallurgy Parts Association
- Metal Powder Producers Association
- Powder Metallurgy Equipment Association
- Metal Injection Molding Association
- Refractory Metals Association
- Association for Metal Additive Manufacturing

APMI International:

APMI International is a worldwide technical society for individuals working in, or interested in developments related to, PM technology.

Both are headquartered at 105 College Road East, Princeton, New Jersey 08540-6692; (609) 452-7700; Fax (609) 987-8523. info@mpif.org ~ apmi@mpif.org

Visit our websites: mpif.org • pickpm.com • mimaweb.org • ipa-web.org • amanweb.org • apmiinternational.org • cpmtweb.org

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