

## FASTENING

Edited by Jean M. Hoffman

# Sleek designs hinge on strong rotary joints

Metal injection molding lets designers create tiny custom hinges for handheld electronics.

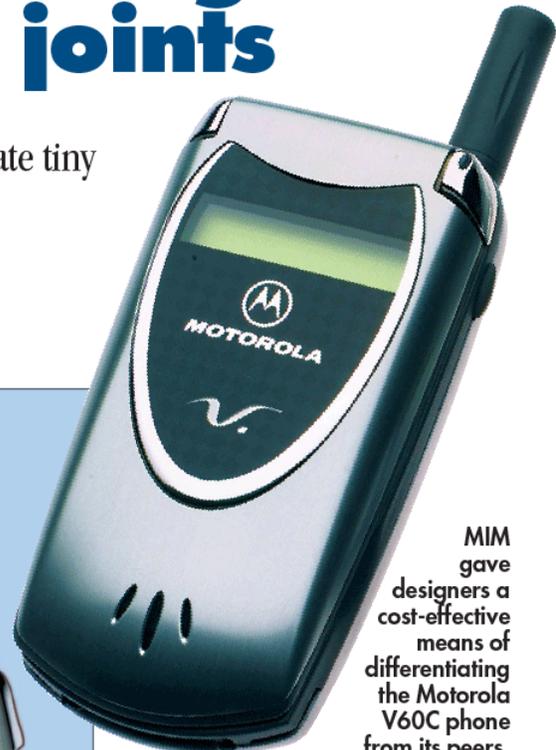
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The quest for quality at competitive prices is pushing designers of handheld electronics to think of lean manufacturing for components. It is wise to take a closer look at alternative manufacturing technologies early in the design cycle. This is one way to beat the competition to market and help differentiate a product from the rest of the pack.

One such alternative technology is metal injection molding (MIM). It is increasingly adopted to fill the niche where other metalworking processes are not viable. Typical examples are in miniature components such as rotary hinges found in cell phones, PDAs, laptops, tablet PCs, and camcorders.

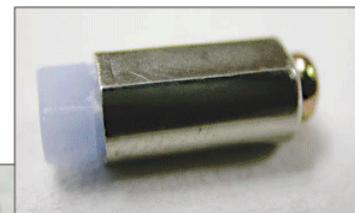
MIM combines the lean manufacturing benefits associated with plastic injection molding (design freedom, parts consolidation, and high-production volumes) with powder metallurgy to transform metal powder into solid, net-shape components that would be difficult or impossible to manufacture with traditional metalforming processes. MIM provides near-theoretical densities that bring mechanical properties superior to most other forms of powder metallurgy and that approach those of wrought alloys.



MIM gave designers a cost-effective means of differentiating the Motorola V60C phone from its peers. Advanced Materials Technologies Pte. Ltd. molded the hinges from stainless steel and polishes them to a mirrorlike finish.

The high demand for electronic device hinges has developed into a market with well-established industrial standards and specifications. Historically made from POM (polyoxymethylene), hinges came in several standardized designs (nude and can), each with predefined torque values, opening angles, and dimensions.

MIM hinges, however, are becoming more widely used because the process lets designers customize hinges for function as well as aesthetics. MIM hinges are mostly found in cell phones with flipping or folding "clamshell" de-



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dard nude or can styles with predefined torque, opening angle, and dimensions.

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### MIM PRIMER

Metal injection molding is a manufacturing option for producing complicated parts in medium to high volumes (10,000 to over 1,000,000 parts annually). The technique uses fine (<20- $\mu\text{m}$ ) metal powders that are intimately mixed with various thermoplastic binders in what's called a feedstock. The feedstock injects into molds similar to those used in plastic injection molding forming a composite "green" part.

A multistage powder-metallurgy process first removes most of the thermoplastic binder from the part using thermal or solvent processing, or a combination of both. The so-called debinding method employed is dependent on the polymer formulation as well as part cross section. Following binder removal, parts are sintered with a temperature and atmospheric profile specific to the alloy being processed. This removes the remaining traces of binder and as the temperature rises, the powder-metal particles fuse together, pore volume shrinks, and grain boundaries form at particle contacts.

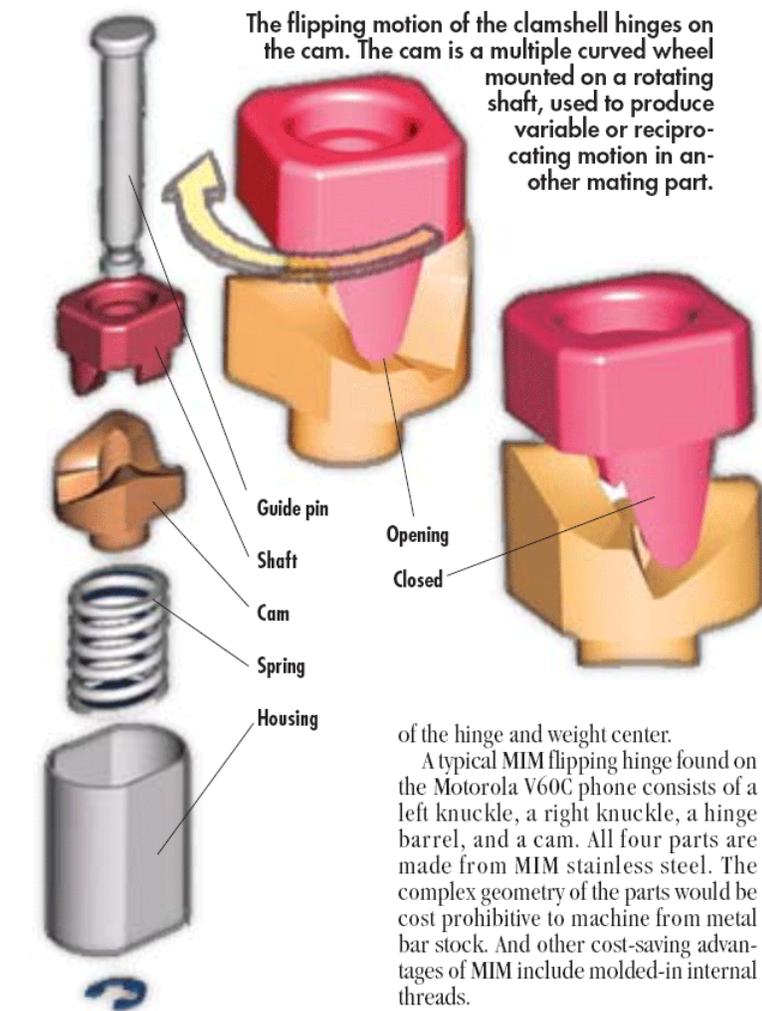
Sintering temperatures for MIM range from 1,200 to 1,400°C. The fine particle size in combination with the high sintering temperatures produces greater sinter densities than those possible with conventional powder-metallurgy processes. MIM densities between 96 and 99% theoretical are common and interconnected porosity is less than 0.2%.

MIM is well suited for parts weighing up to 250 gm. Cross sections are typically less than 0.25 in. (6.35 mm). However, parts are not restricted to this combination of mass and cross section. Tolerances are on the order of  $\pm 0.3$  to 0.5%, although specific dimensions can be held as close as  $\pm 0.1\%$ .

Injection molding accurately duplicates mold surfaces. This results in parts having as-sintered surface finishes of <32 RMS (microinches). Common secondary operations, such as plating or heat treating, are also used to enhance the look of the part or boost performance. Because interconnected porosity is so low, parts don't need to be resin impregnated prior to plating and close control over case depth is possible in carburizing.

The **Metal Powder Industries Federation (MPIF)**, Princeton N.J., offers Standard 35, *Materials Standards for Metal Injection Molded Parts*. The standard covers the most commonly used MIM materials with details on chemical and mechanical properties of each.

### The Phoenix Korea hinge design



signs where the hinges connect the base to a folder unit.

Unlike hinges of doors, cell-phone hinges must be able to control the angle of opening. Popular angles include 30, 60, 90, 120, and 150°. But free-stop designs, where the folding stops at any angle, are gaining in popularity.

The flipping motion of the clamshell hinges on the cam. The cam is a multiple curved wheel mounted on a rotating shaft that produces variable or reciprocating motion in another mating part. Torque values are primarily derived from the shaft, cam, and spring. Secondary factors that affect torque are friction of the cam curve, tolerance between the base unit and the folder unit, the weight center location of the folder unit, and the distance between the axis

of the hinge and weight center.

A typical MIM flipping hinge found on the Motorola V60C phone consists of a left knuckle, a right knuckle, a hinge barrel, and a cam. All four parts are made from MIM stainless steel. The complex geometry of the parts would be cost prohibitive to machine from metal bar stock. And other cost-saving advantages of MIM include molded-in internal threads.

But consumer demand for more features is driving hinges toward two degree-of-freedom movement. Flip-and-twist hinges combine two rotary hinges with axes that are perpendicular to each other. This lets the clamshell flip open then twist 180°. A leader in flip-and-twist development is Korean-based **Phoenix Korea Co. Ltd.** The company specializes in a variety of specialty folder or flipper-type cellular phones equipped with multistep and free-stop hinges. The flip-and-twist concept is being extended into other consumer electronics including camcorders, digital cameras, PDAs, and notebook PCs.

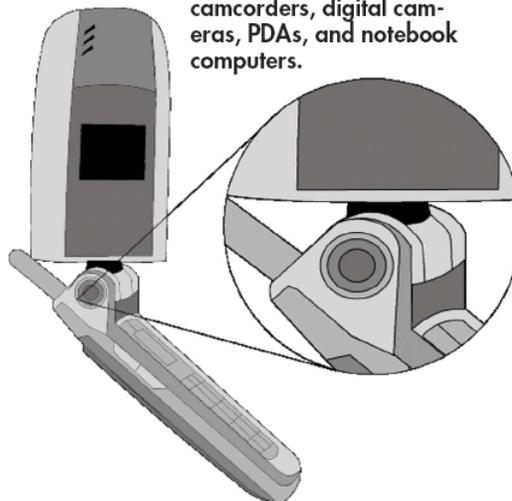
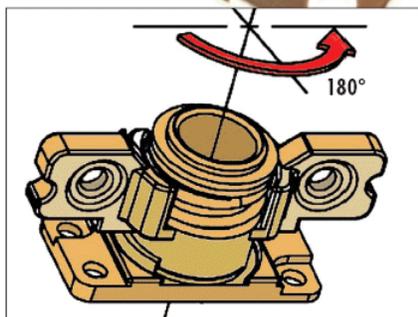
### MIM HINGE-DESIGN CONSIDERATIONS

The design of MIM hinges follows the basic MIM principles, which are material

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Stainless steel is used for strength and performance of flip-and-twist hinges for cell phones. Additionally, the design freedom associated with MIM coupled with miniaturization of cellular phone components gives more options for flexible printed-circuit-board pathway design and protection.



Flip-and-twist hinge design adds a bit more whimsy to standard clam shell cell phones. The concept is currently being investigated for camcorders, digital cameras, PDAs, and notebook computers.

selection and geometry consideration. The strength of the hinges plays a significant role in determining the platform and size of the product. Material selection needs to focus on the following:

**Strong fatigue strength.** It's common for hinges to go through flip testing to establish the reliability of the flip mechanism. The testing standard is usually a minimum of 100,000 repetitions at intervals.

**Corrosion resistance.** As the hinges see humidity and perhaps manual handling, corrosion resistance becomes critical. The industry demands that hinge materials survive salt-spray and humidity tests.

**Magnetism.** Use of magnetic material needs careful study as it might generate RF interference that would interfere with the intended function of the device.

**Hardness.** Appropriate hardness will keep the hinges from eroding or denting during use. Teflon coating and grease can also be applied to the hinges to reduce friction and boost wear resistance.

**Density.** A density above 97% theoretical is needed to ensure material integrity, especially when there is a need for polishing to fulfill cosmetic requirements.

Stainless steels such as 316L, 17-4PH, and 440C stand out as popular material choices.

### GEOMETRY CONSIDERATIONS

**Geometry.** With MIM, design complexity is free. Parts consolidation, net shape geometry, and molded-in features such as threads and holes can result in tremendous savings during subsequent operations such as secondary finishing and final assembly.

**Seating surface.** Parts must be placed onto substrates and loaded into a furnace for debinding and sintering so a seating surface must be designed into the part. For non-self-supported parts fixtures will be required during debinding and sintering.

**Field-Programmable Circuit-Board Pathway.** The hinge geometry must accommodate a path for the FPCB to connect the base and the folder unit so data can transfer from one to the other. A diameter of 5.7 mm is usually required for the FPCB to pass through the hinge. The design freedoms afforded by MIM together with the miniaturization of cellular phone components creates greater flexibility in FPCB design and protection. ■

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### Typical stainless-steel alloy properties

| PROPERTY               | 316L   | 17-4PH | 440C   |
|------------------------|--------|--------|--------|
| Tensile strength, kpsi | 75     | 130    | 90     |
| Yield strength, kpsi   | 25     | 106    | 59     |
| Elongation, %          | 50     | 6      | 10     |
| Hardness               | 67 HRB | 27 HRC | 90 HRB |

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