

Kinetics
METAL INJECTION MOLDING

MIM DESIGN GUIDE

The background features a complex technical drawing of a mechanical assembly, possibly a mold or a machine component, rendered in a light gray wireframe style. A large white circle is centered on the page, with a white crosshair intersecting at its center. The text 'MIM DESIGN GUIDE' is written in a bold, yellow, sans-serif font, oriented vertically and centered within the circle. The overall color scheme is dark, with the yellow text providing a strong contrast.

Welcome to our MIM Design Guide



Metal Injection Molding (MIM) or Powder Injection Molding (PIM) is a net-shape process for the production of highly complex metal components in medium to very high annual volumes. This design guide is intended to serve as a reference for applying MIM/PIM design principles to new components and evaluating existing components for possible conversion to this manufacturing technology. Properly designed MIM parts maximize the economic benefits of the process by ensuring that net shape results and targeted dimensional Cpk's are attained.

Kinetics' organization includes an exceptional group of design engineers, metallurgists, process engineers, manufacturing operators and quality engineers – all with substantial experience in Metal Injection Molding (MIM) or Powder Injection Molding (PIM). Our experienced technical staff is complimented by state-of-the-art processing and analytical equipment, and can assist your efforts to develop MIM applications or convert parts from other manufacturing processes.

When it comes time to request a quote or design assistance from Kinetics, you can submit your electronic part data by e-mail or through our secure FTP site. Kinetics operates Pro Engineer Wildfire, Inventor and AutoCad/Mechanical Desktop software applications. Kinetics prefers to receive native files, but when they are unavailable, CAD files should be submitted in the following formats: .pdf, .dxf, .iges, .stp (.step) or surface iges.

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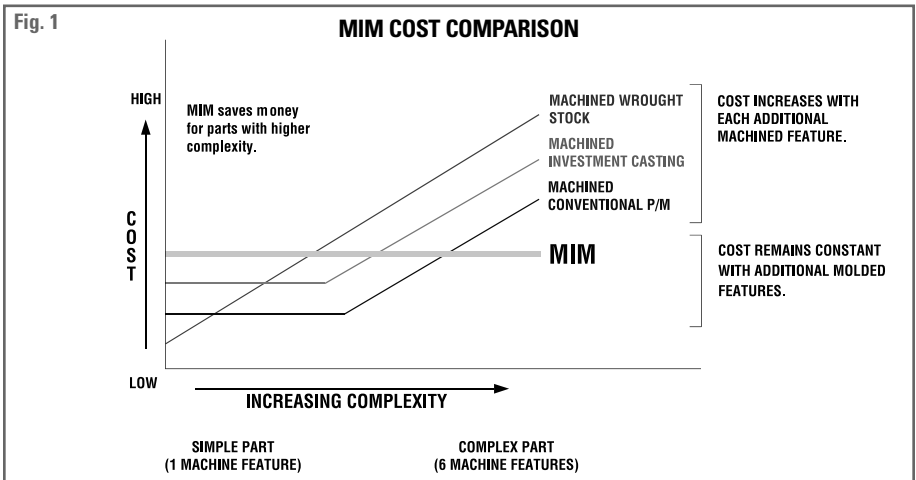
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MIM application characteristics

Metal Injection Molding or MIM (also referred to as Powder Injection Molding or PIM) is a net-shape process for producing solid metal parts that combines the design freedom of plastic injection molding with material properties near that of wrought metals. With its inherent design flexibility, MIM is capable of producing an almost limitless array of geometries in many different alloys. Today, MIM is serving critical performance applications in a wide range of products including, automotive fuel and ignition systems, aerospace and defense systems, cellular telephones, dental instruments and braces, electronic heat sinks and hermetic packages, electrical connector hardware, industrial tools, fiber optic connectors, fluid spray systems, hard disk drives, pharmaceutical devices, power hand-tools, pumps, surgical instruments, and sporting equipment.

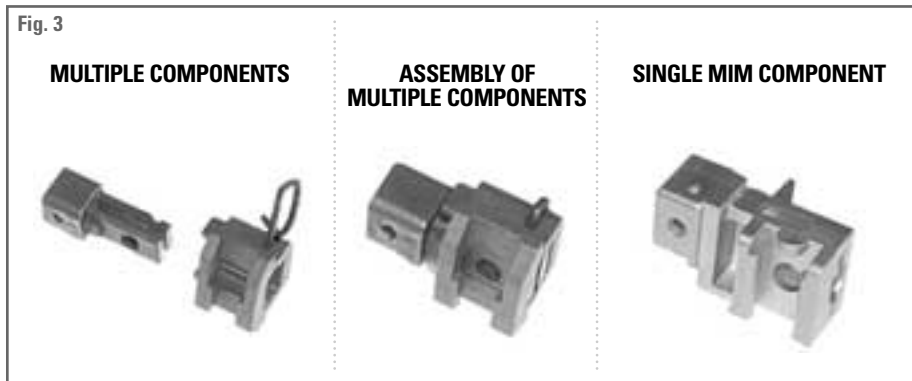
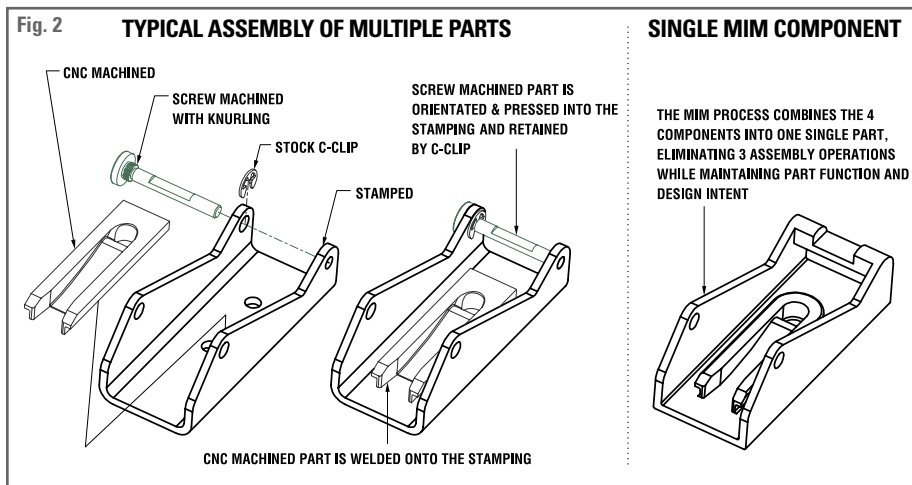


An emphasis on plastic part design flexibility should be applied to metal part geometries developed with the MIM process in mind. Traditional metalworking technology limitations should be ignored. The MIM process can allow significant shape sophistication, the combination of multiple parts, multiple feature/functions within a single component, product assembly enhancement features, miniaturization of mechanical assemblies, mass reduction, and custom tailored physical properties for the intended end use are all possibilities with MIM.



..... **MIM Application Characteristics (continued)**

A very effective way of utilizing MIM's inherent design freedom is to combine multiple components in an assembly into a single MIM component. Fig. 2 illustrates the conversion of a 4-component assembly into one MIM component. This eliminates 3 assembly steps and related costs, plus reduces the number of parts that have to be purchased, tracked, and managed through inventory. The resulting MIM component is stronger, more cost effective, and is produced closer to the original design intent than the assembly. Fig. 3 displays an actual application of this design approach. Three parts were combined into one, which provided improved product performance at a much lower cost.



While the best cost benefit of MIM generally comes from applications designed with the technology in mind, successful technology conversions routinely take place. Kinetics' design engineering team can assist your efforts to evaluate potential technology conversions from a preliminary cost analysis to a comprehensive review of dimensional tolerance specifications.

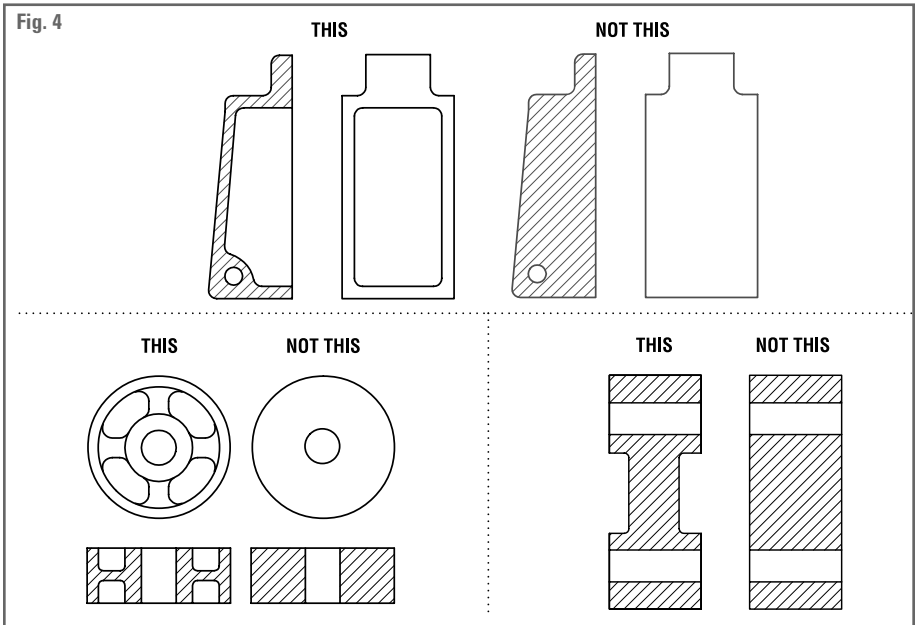
Uniform Wall Thickness, Coring & Mass Reduction

Since injection molding is employed as the shape forming process step in MIM, part designs can avoid the limitations of traditional metalworking processes. For example, machining involves the removal of material from a solid shape to get to the desired final component design. As a result, design engineers are limited to design

decisions that can be readily produced on an economical basis and those which do not violate the design limitations of machining. The benefits of removing excess material for reduced part mass is generally not considered as this design approach would add incremental machining costs. With MIM, as is the case with plastic injection molding, design engineers have the freedom of starting with a "clean slate," and building up their component geometry by placing material only where it is needed for function and strength. This serves several benefits for the MIM process and the customer. The very fine metal powders used in the MIM process are expensive, and any opportunity to limit the amount of material required in a component helps minimize the final MIM part cost. Additionally, maintaining a uniform wall thickness throughout a component reduces the likelihood of molding process flaws, thus improving the overall part quality, cosmetics, and generally improves the resulting dimensional tolerances that the MIM process can provide.



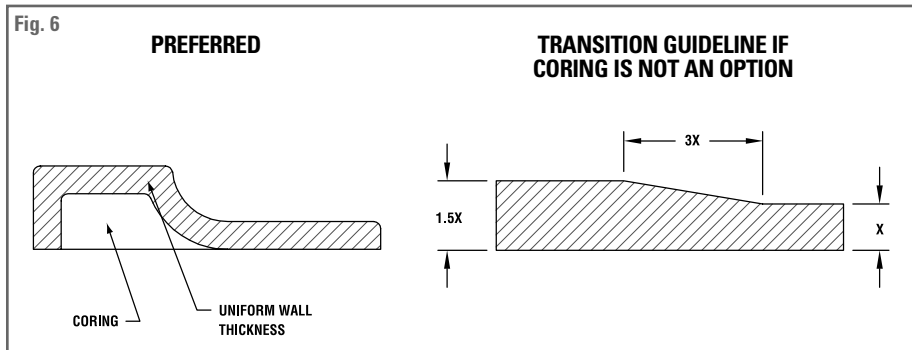
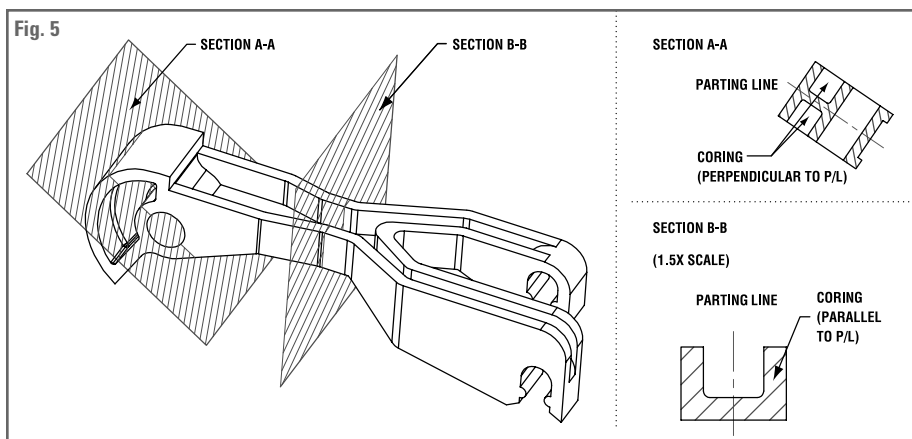
Fig. 4 illustrates several preferred geometries accomplished through coring to create uniform walls. You will also note instances where unnecessary material



..... Uniform Wall Thickness (continued)

has been removed or cored out in areas with thick cross sections. Coring can be done either parallel or perpendicular to the parting line. Fig. 5 illustrates both types of coring. Coring perpendicular to the parting line (Section A-A) can be produced with cores, which are fixed features on either half of the mold. Coring parallel to the parting line (Section B-B) can be produced with slides, which are moving components in a mold. The slides are usually placed at the parting line and move parallel to it. Slides add complexity and costs to a mold, so if the design permits, coring perpendicular to the parting line is preferred approach.

Remember, when designing a MIM part, or when coring out an existing design, maintaining a consistent uniform wall thickness throughout the part is the primary objective. Again, in a MIM component, uniform walls are desired for higher precision, more repeatable dimensional capability, lower processing costs and improved aesthetics. If, however, varying wall thickness cannot be avoided, a gradual transition between differing wall thicknesses should be provided and every attempt should be made to avoid abrupt changes. Fig. 6 provides a recommended wall thickness transition ratio for those situations when uniform walls cannot be achieved.



Sintering Supports

During the debinding and high temperature sintering processes, molded parts (or green parts) shrink about 20%. While the parts are shrinking and before the parts can fully sinter, the forces of gravity and friction (from shrinking) may distort the parts if they are not adequately supported. Ideally, MIM components should be designed with a large flat surface or with several component features that have a common plane. This design approach allows the use of standard or flat debinding and sintering plates or trays, and eliminates the need for custom or part specific debinding and sintering supports. These custom or part-specific supports can be expensive to produce and represent added tooling costs for the customer. Fig. 7 illustrates a MIM component that is fully supported and placed onto a standard plate without the need for special supports.

However, if a single flat surface or plane cannot be provided, part specific debinding and sintering supports will be needed. There are various types of specialized supports that can be used. The simplest type of debinding and sintering support is a ceramic strip. Fig. 8 illustrates a typical use for a ceramic strip, which is often used to support cantilevered features that could “sag” in the high temperature sintering process. The strips come in different heights and widths to meet the

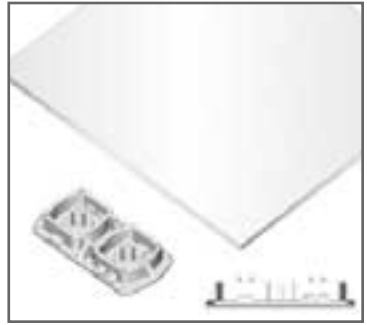
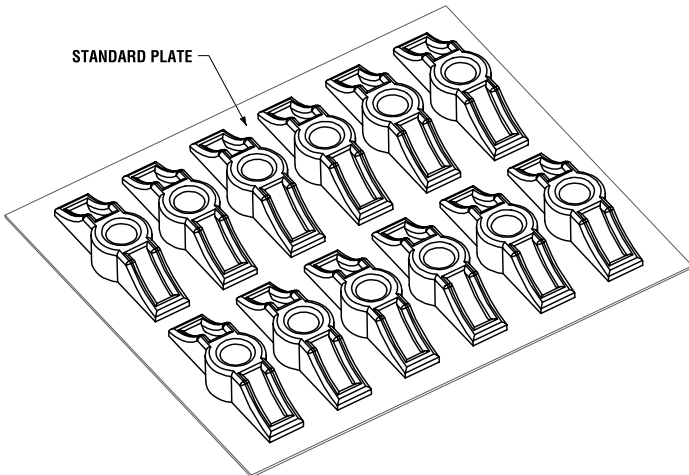


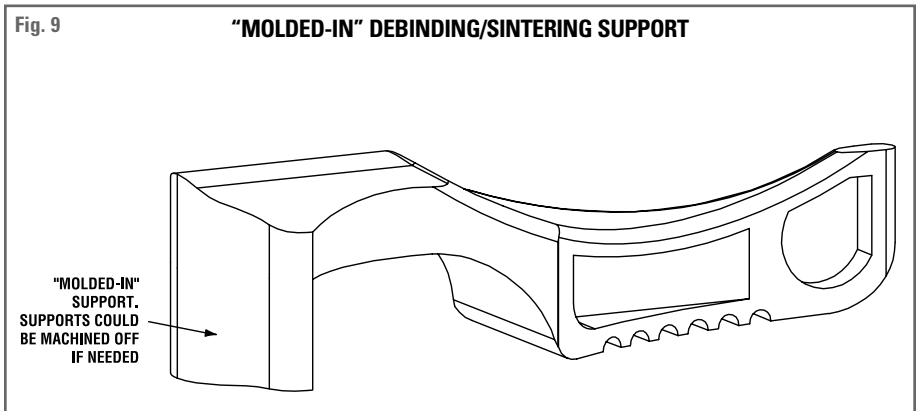
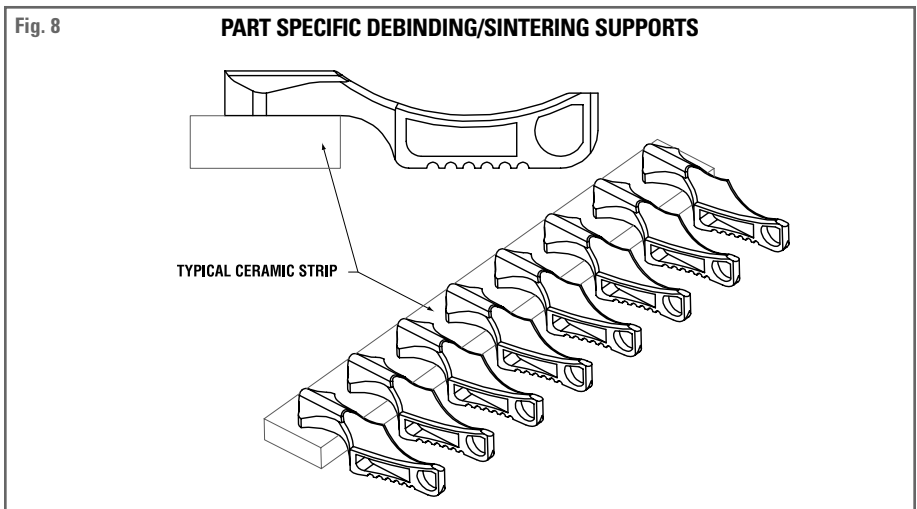
Fig. 7

STANDARD DEBINDING/SINTERING PLATE

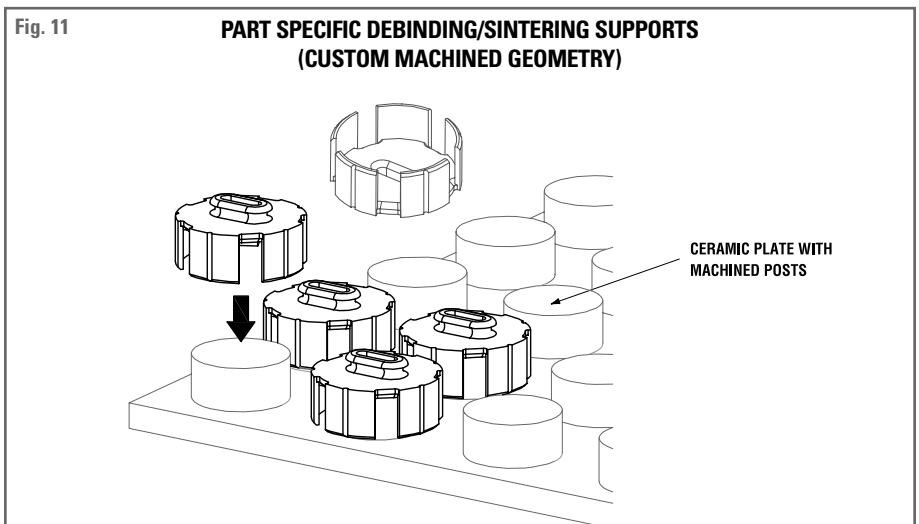
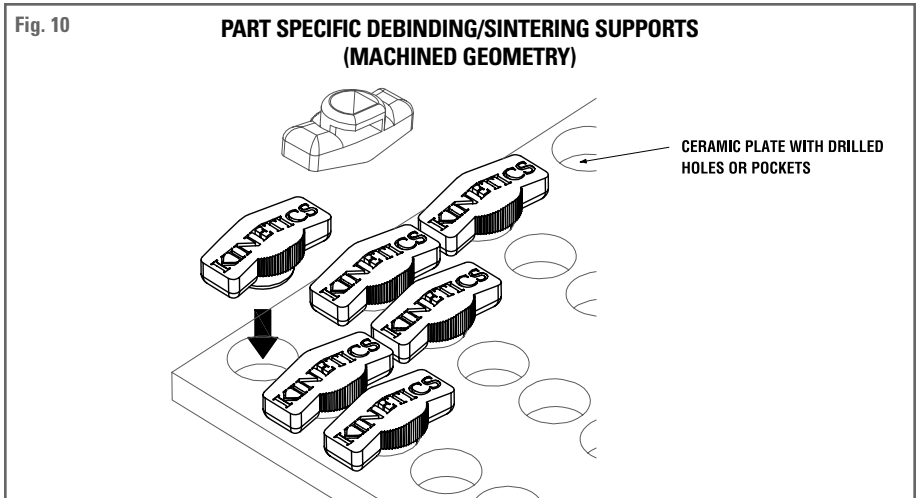


finished part's dimensional requirements. If the design permits, ceramic strips can be avoided by designing "molded-in" supports. This would eliminate the need for the additional tooling costs, but would add a non-functional feature to the component. Fig. 9 shows how a "molded-in" feature could eliminate the need for supports.

An increase in complexity and cost from ceramic strips are ceramic plates with machined features. Attempts are made to minimize the cost of these machined plates by limiting the plate features to holes or grooves. These types of supports are more expensive than simple ceramic strips, but can fully support features that are more complex. Fig. 10 illustrates an example geometry that would require this type of support.

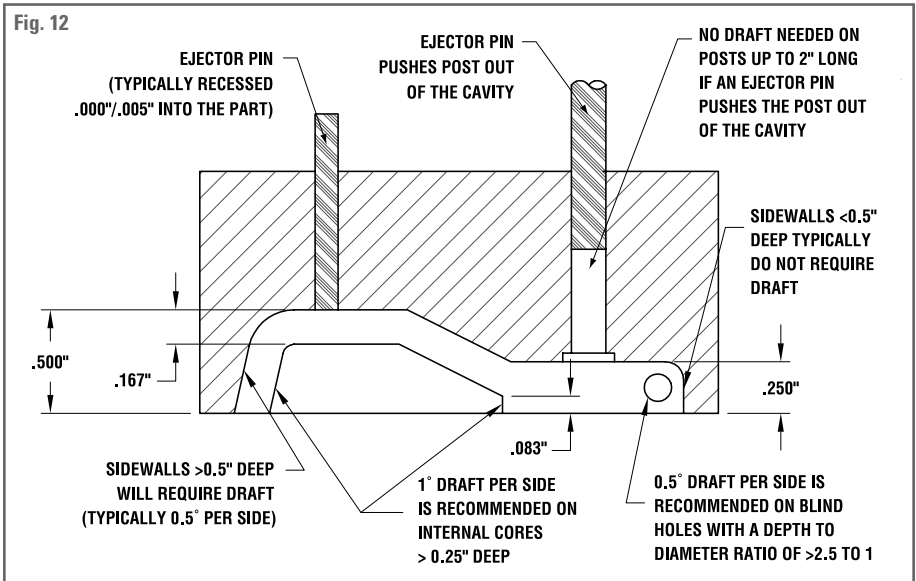
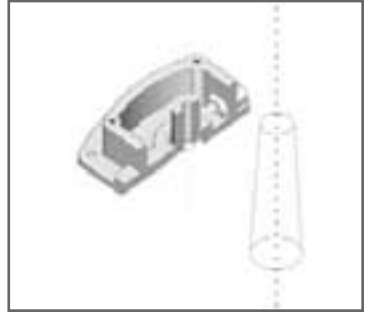


It is also possible to machine custom ceramic plates for supporting highly complex part geometries. Fig. 11 shows a MIM part that is placed on machined posts. If the part were simply placed on the thin walled legs, the legs would likely “drag” open when the part shrinks 20% during the sintering process. Placing the part upside down is not an option due to the small feature on the top. The intent of the posts on the custom ceramic plate is to suspend the part so the bottoms of the legs are not making contact with the base of the plate. In this example, the effects of gravity can actually help keep the legs straight. This type of support plate represents among the most expensive type of supports used by the MIM process.



Draft - Where and When Required

This is a design aspect where MIM often differs from plastic injection molding requirements. Generally, MIM components do not require draft. There are a couple of factors that contribute to this ability. First, the MIM feedstock is highly loaded with metal powders that retain heat long after the molding cycle has been completed. Post molding shrinkage that occurs with plastic parts while they are still in the mold, occurs for MIM parts during the first several minutes after they have been removed from the mold. This allows the part to be ejected before it can cool and shrink around cores and/or other mold cavity features. Secondly, the polymer binder used in MIM feedstock acts as a lubricant to assist in the ejection of the part from the mold cavity. With these influences in mind, there are circumstances when draft should be provided in MIM component designs. Fig. 12 illustrates some of these circumstances.

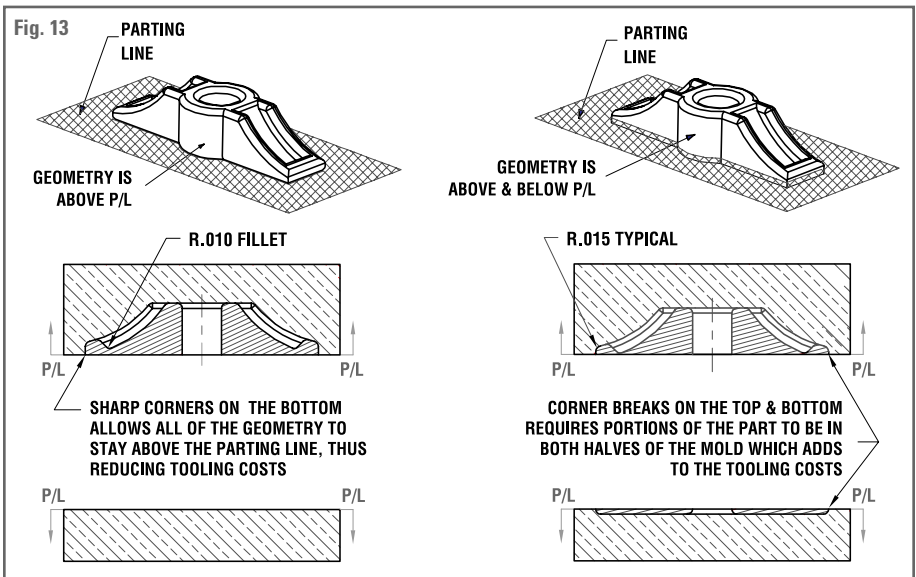


Corner Breaks & Fillets

One of the intrinsic benefits of MIM is the ability to produce corner breaks and fillets. Not only do corner breaks and fillets play several important roles in a good MIM component design, but they also provide design engineers with design advantages not readily available in some metalworking processes. In addition to providing improved injection molded part quality, these design advantages include, improved part strength, elimination of stress concentrations, and softening of sharp corners for aesthetics and handling.



Typically, corner breaks should be kept larger than .005" radius. Internal and external corner breaks less than .005" radius will induce stress concentrations in the part and will be difficult to fabricate in the mold. Fig. 13 illustrates an exception where a sharp corner is preferred over a generous radius. The figure shows a MIM component and mold design that benefit from having sharp corners located on the bottom of the part. In this case, the sharp corners allow the part geometry to be kept in one half of the mold, which simplifies the mold design, reduces the mold cost, and does not jeopardize the part's strength. Should a radius be required along the bottom edge of the part, it can be readily produced, but it should be noted that the part must now have portions of it produced in each half of the mold. In addition to adding cost to the mold, the designer should expect a witness line around the profile of the part at the parting-line location.



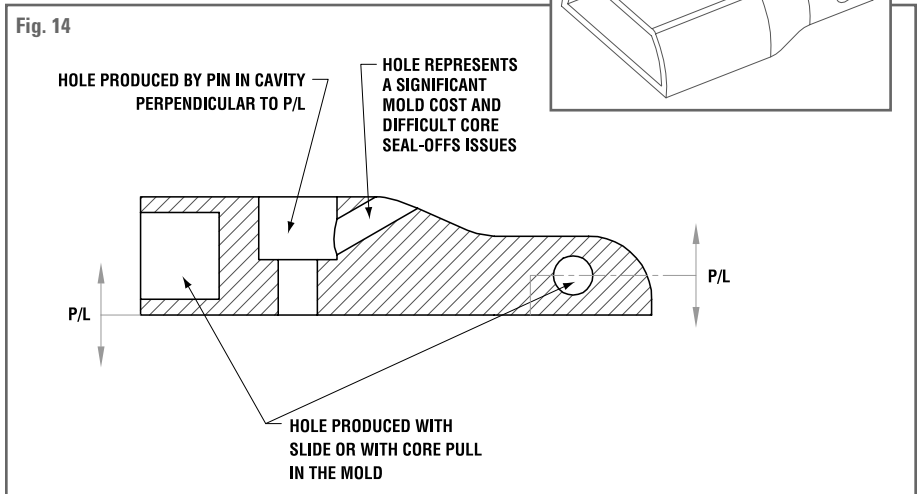
Holes & Slots

Holes and slots can be readily produced by the injection molding process used by MIM, and generally, can be accomplished at no additional cost to the piece price. However, adding these features does increase the cost and complexity of the mold. Also keep in mind that beyond representing obvious functional features, holes and slots can also be used to reduce part mass and provide uniform wall thicknesses.

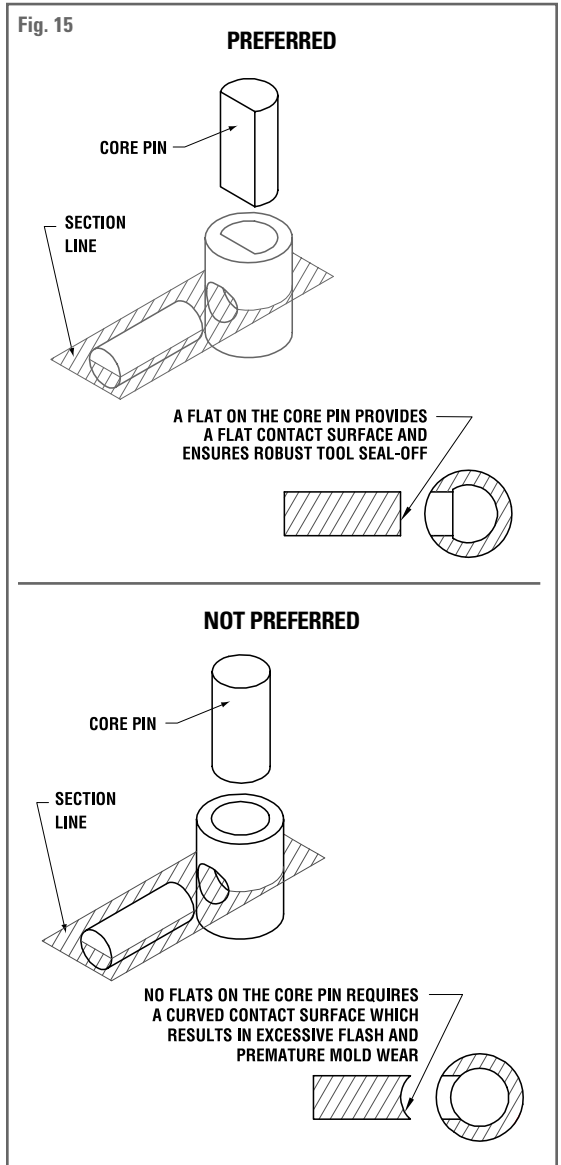


It is important to be aware of the type and direction of a hole and how it could affect the cost and the robustness of the mold. Fig. 14 shows several types of holes, their direction relative to the parting-line, and their impact on the mold. Holes that are perpendicular to the parting-line represent the easiest mold design approach and the lowest cost to incorporate in the mold. Holes that are located parallel to the parting line are readily applied, but the tooling costs more than holes located perpendicular to the parting-line as they require mechanical slides or hydraulic cylinders to actuate them during part ejection. Holes that are set at an angle to the parting-line are also possible, but the mold construction and the mechanism to actuate them becomes very expensive and in many cases the mold features mandate more frequent maintenance downtime and related upkeep costs.

Cores and slots that intersect one another can also create complex part features. However, when employing intersecting features, the mold construction and robustness must be considered. Fig. 15 shows the advantages of using a D-shaped hole as an ideal seal-off surface for an intersecting



hole. In this case, two flat surfaces are sealing against one another providing a tool that will be easy to maintain and less likely to generate unacceptable flash during the molding process. The alternative displayed in the figure shows the least attractive approach, which requires one of the cores to have a contoured or profiled face to match the core or hole that it will be sealing against during the injection portion of the molding process. In circumstances like these, the core orientation is critical and the feathered edges are likely to wear more rapidly affecting the shape and size of the molded feature. Mold flash is also a concern in these situations.

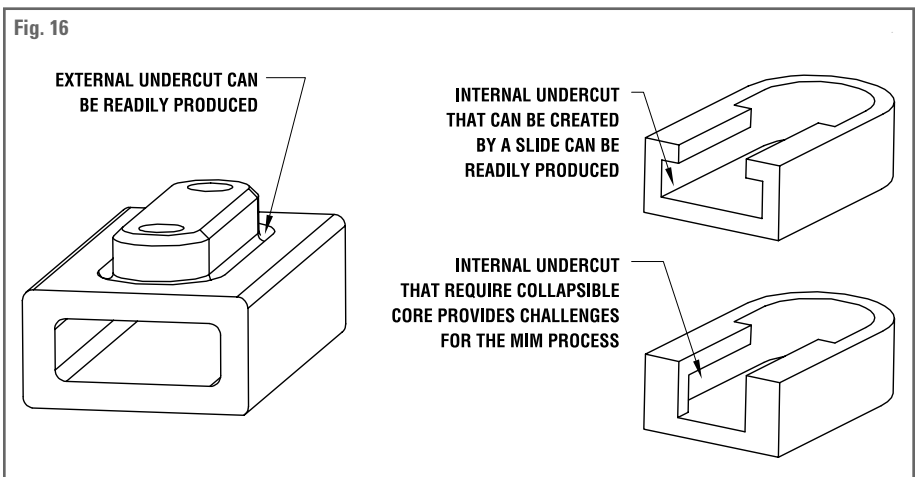


Undercuts - External/Internal

External undercuts can be produced readily with the MIM process. The component on the left in Fig. 16 shows an external undercut that provides relief for burrs on a mating stamped component. The ability of MIM to provide the feature by placing it in the mold design eliminates the need and related cost associated with removing the burr on the stamping. Essentially, an increased level of complexity can be provided in the MIM part without effecting the part's cost, while at the same time the MIM part design eliminates the need for a secondary deburring or chamfering process on the stamping. Consideration of product assembly requirements should always be considered when designing components to be produced by the MIM process.



Internal undercuts are possible with MIM under the right conditions. Internal undercuts that can be produced with a mechanical or hydraulic actuated slide can be readily produced. Fig. 16 (top, right) shows a "T-slot" internal undercut that can produce with a slide. Fig. 16 (bottom, right) also shows a similar component but the internal undercut requires a collapsible core. This undercut requires the internal feature to be large enough to accommodate a robust collapsible core. Generally though, MIM components are small and collapsible cores are often impractical and some times impossible to produce that are robust enough to take the injection pressures used by the MIM molding process. Collapsible cores also provide challenges in maintenance to minimize flash. Seek advice from Kinetics' Applications Engineers when considering such features.



Threads

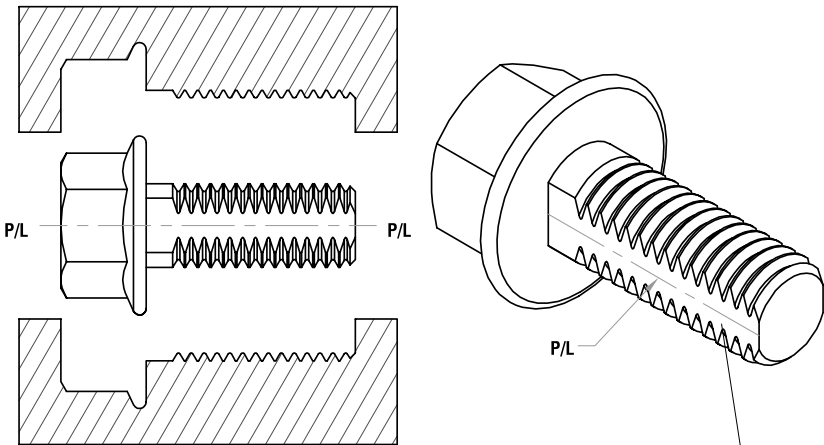
Internal threads can be molded directly into the component using unscrewing cores. These mold features and functions are costly to produce, and as a result, are only applicable to high volume applications. For lower volume part applications, conventional tapping operations can be employed.



External threads can be molded directly onto the component thus eliminating the need for secondary thread-forming operations.

Molding external threads is almost always a more cost effective approach than forming the threads with a secondary operation. Generally, a small flat, typically .005", at the parting line should be incorporated into the design. The recessed flat, shown in Fig. 17, will insure proper mold seal-off and reduce the opportunity for parting-line vestige to interfere with component function. Without the presence of a flat along the parting-line, you can expect problems with flash to develop in the root of the threads within the production of very few parts. This will likely increase tooling maintenance and down time.

Fig. 17



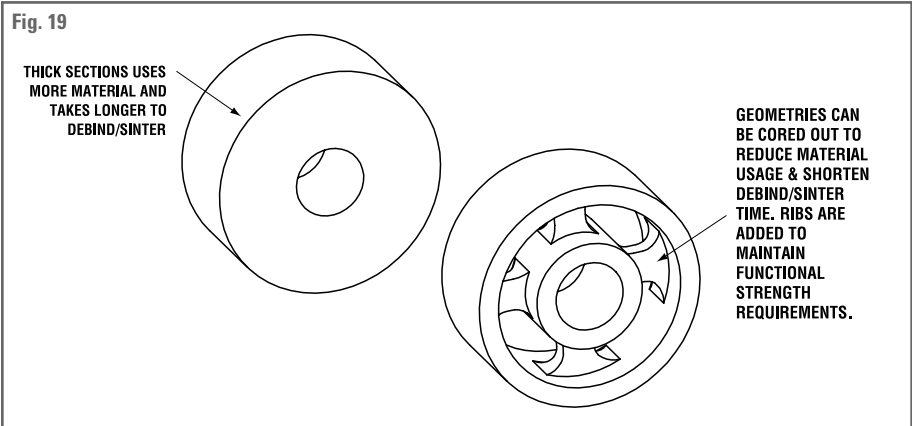
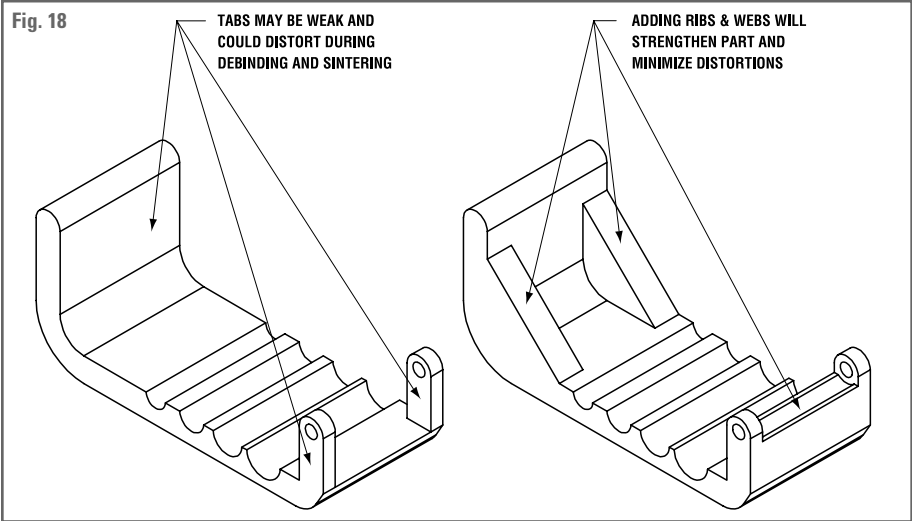
SMALL FLATS, TYPICALLY .005", IMPROVES SEAL-OFF AND ENSURES THAT ANY PARTING LINE VESTIGE DOES NOT INTERFERE WITH THE FUNCTION OF THE COMPONENT

Ribs & Webs

Ribs and webs are an efficient way to increase your part strength, and minimize the effects of dimensional variation caused by the substantial shrinkage, which occurs during debinding and sintering. As with plastic injection molding, ribs and webs also improve the molding process and provide better dimensional control. Fig. 18 details how ribs and webs can be added to improve the mechanical design and provide a more robust MIM component.



Another application of ribs is displayed in Fig. 19, where they are used as a means to provide coring for part mass reduction without effecting the intended end use or strength of the component.

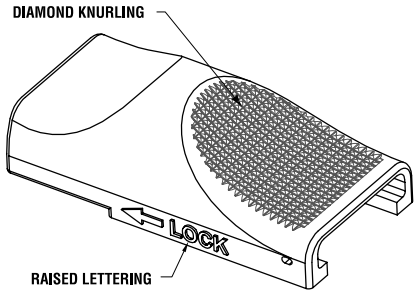
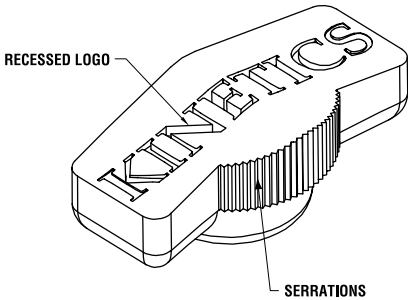


Knurling, Lettering, & Logos

MIM is capable of producing knurling, lettering, logos, date coding or other designs directly into the component without added costs to the piece price. These features can either be raised or sub-surface. Fig. 20 depicts various examples of this capability. MIM can provide high levels of feature detail, including relatively sharp diamond knurling. Virtually any feature you can imagine molding is possible in solid metal parts with the MIM process.



Fig. 20



Gating - Types & Locations

Like plastic injection molding, MIM parts require consideration for gate locations. However, MIM gates are generally much larger than those used on plastic part designs due to the high metals loading of MIM feedstock.

In most cases, gates are located at the parting line of the mold. The impact of the gate location on the component must be considered during the design phase, as it can be a careful balance between manufacturability, part function, dimensional control, and aesthetics. Gates will leave a slight vestige, and should not be located on a dimensionally or a visually critical surface.

In general, the gate is placed at the thickest cross-section to allow the material to flow from thick to thin cross-sections. Additionally, the location of the gate(s) should be placed to allow uniform filling of the mold cavity.

Fig. 21-23 show examples of various gate types, as well as their typical use, and preferred locations.

Fig. 21 shows an illustration of an edge gate. The following characteristics are typical for an edge gate:

- Gates are typically removed manually and are not suited for high annual volume applications as they require removal by manual or automated means. Regardless, the removal process is an additional process step and cost.

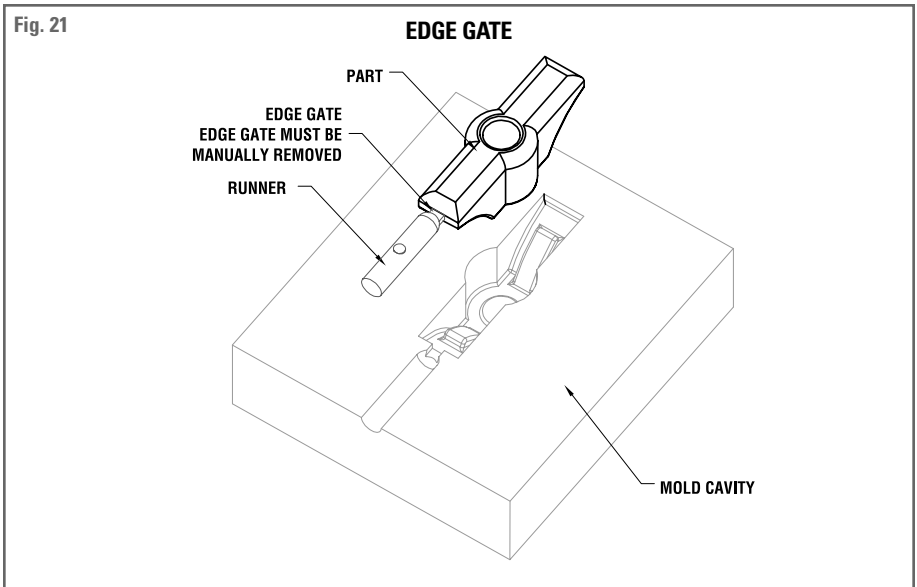
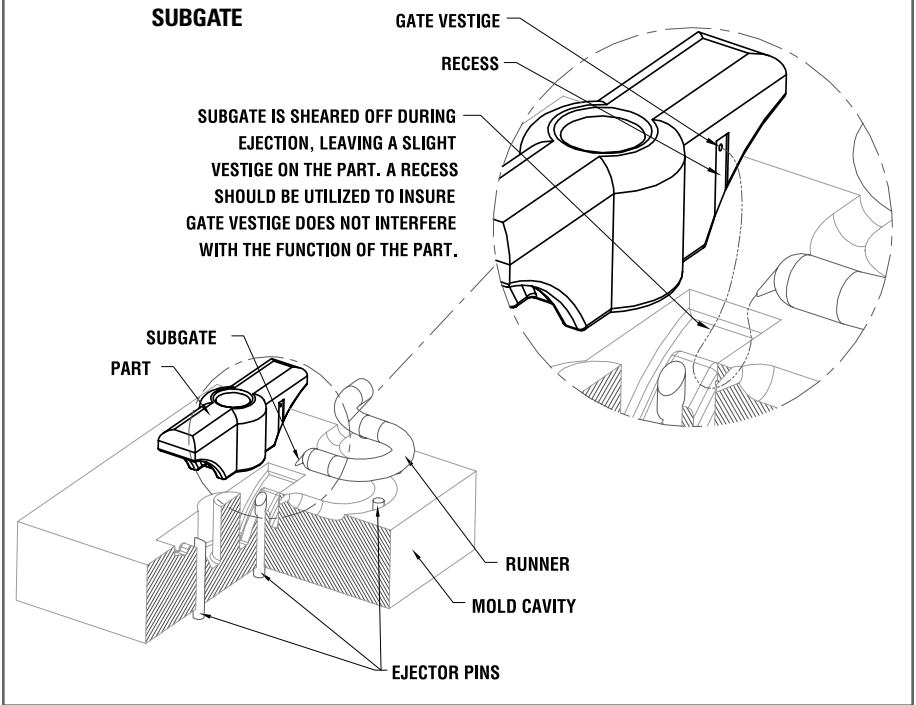


Fig. 22



- Suited for low to medium annual volume applications.
- Recessed gates are preferred to minimize vestige above functional component surfaces.
- Normally located along the parting line.

Fig. 22 details a submarine or sub-gate, which has the following characteristics:

- The gate is automatically sheared off from the part during the part ejection portion of the molding process.
- Suited for low to high annual volume applications.
- Leaves minimal gate vestige or breaks off below the surrounding component surface.
- Sub-gates should be placed on a recessed surface to minimize vestige above functional component surfaces.

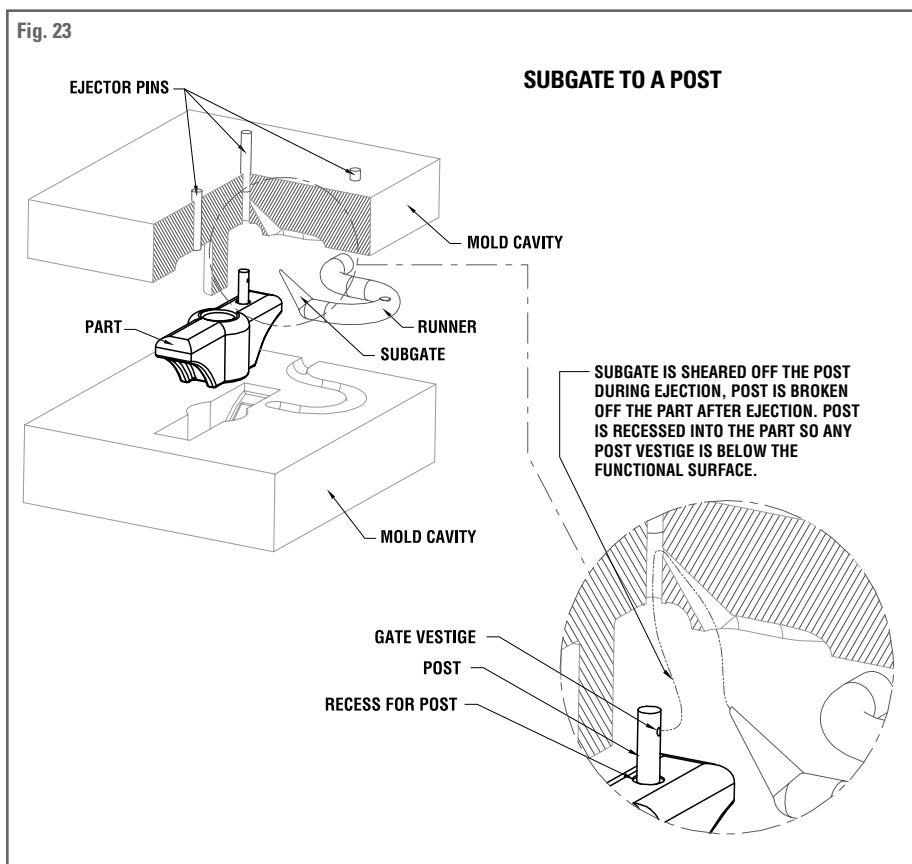
Fig. 23 illustrates a submarine or sub-gate to a removable post. This gating approach has the following characteristics:

- The gate is automatically sheared off from the post during the part ejection portion of the molding process.

..... Gating Types & Locations (continued)

- The post is removed after the part is out of the mold, and this removal process is not typically automated.
- The post is preferably located in a recessed pocket on the MIM component so the post can be broken off below the component surface.
- Suited for low to medium annual volumes.
- The post and related recess or pocket should be located on non-cosmetic surface.

Other gating techniques common to plastic injection molding can also be applied to MIM parts including, 3-plate molds with direct gating and hot-runner systems for direct gating. Generally, any technique utilized in plastic injection molding can be applied to the MIM process.



Sink & Knitlines

Similar to a plastic injection molded part, a MIM part may contain sinks and knit-lines caused by improper part and mold design. Sink (a physical depression on the surface of a part) frequently occurs around thicker sections. The example shown in Fig. 24 (on following page) illustrates how sink can occur when a supporting rib intersects a wall. If the rib is the same thickness as the wall, the intersection of the two, creates a localized thick wall and is susceptible to sink. Decreasing the thickness of the supporting rib eliminates or reduces the potential for sinks. Generally, the thickness of the rib should be about 75% of the thickness of the wall.

Knit-lines can occur when two flow paths of material meet in the cavity and when the flow path is relatively long. Fig. 25 (on following page) shows a knit-line occurring in a cylindrical part with a core in the center and a single gate. The two flow paths have to go around the core before meeting on the opposite side. Due to the long flow path, the two flow fronts of material have cooled down, which creates a visually evident knit-line. Fig. 25 also shows how dual gating the part can substantially reduce and at times, eliminate visible knit-lines. You should keep in mind that visually negligible knit-lines on properly designed MIM parts are superficial and do not represent a structural defect or part performance issue. Generally, knit-lines of this type have a shallow witness that is a little as .0005" deep to .005" deep.



Fig. 24

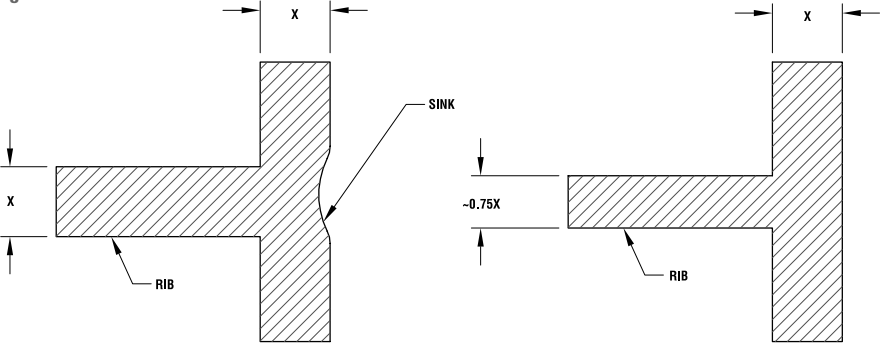
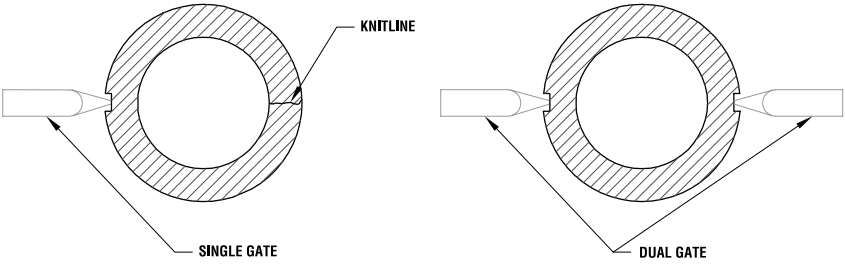


Fig. 25

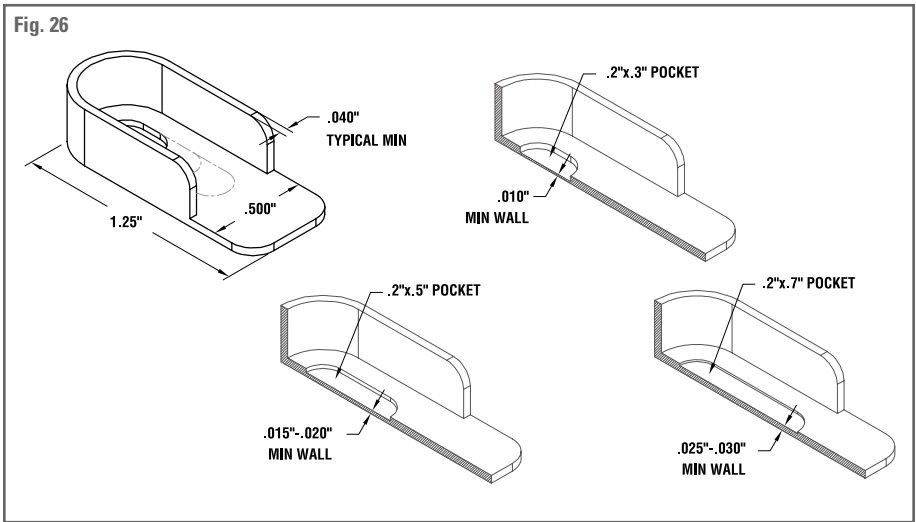


Minimum & Maximum Wall Thickness

The minimum or maximum cross sectional wall thickness on any part is very much dependent on the overall part size and design. The most important issue to keep in mind is the ability to fill the part during the molding step of the MIM process. As an example, a 0.010" wall thickness may be possible if it's localized, but is not possible if it is across the entire length of a 4" long part. Generally, the optimum wall thickness is 0.040" to 0.120" and again, is related to the overall size of the part. Minimizing wall thicknesses also reduces the material content of a part and its cost. Fig. 26 shows a MIM part with a small pocket with a thin wall. The figure illustrates a general guideline on the minimum wall thickness possible depending on the size of the pocket.



At the other end of the spectrum, wall thicknesses as large as 0.500" are possible, but as the wall thickness increases, so does the molding process cycle time, material consumption and debinding and sintering cycles. Each of these increases represents an increase in the part cost.



Flash & Witness Lines

While designing a MIM component, witness lines and areas of potential flash should be taken into consideration. Critical areas from both an aesthetic and functional standpoint should be assessed for possible effects of witness lines or for minimizing the potential for flash. It should be noted that MIM feedstock tends to flash more readily than most plastic materials, and as a result, MIM molds require very precise fits between each of the mold components such as slides, cores, and parting line. Remember, flash generated on a MIM part becomes a metal burr after sintering and is difficult to remove.

Witness lines are an unavoidable result of two mating mold components. Whether along a parting line, or where a core pin seals off against a slide or other mold feature, injection molded material under pressure will be imprinted with the witness mark of two pieces of steel meeting one another. Fig. 27 illustrates the typical witness line to be expected along a parting line. In this example, the parting line is just above the fillet and the part will have a witness mark all around the part at that point. The witness line can often be minimized or removed with a secondary tumbling operation. As discussed in the Corner Breaks & Fillets section of this design guide, if the bottom fillet is not needed and a sharp corner can be tolerated, the full part geometry can be kept in the upper half the mold. This would move the parting line to the bottom of the part and no witness line would be present. A tumbling operation could be performed that would give the part a slight corner break as an alternative to containing the part geometry in both mold halves in order to accommodate a radius along the edge of the part.



The potential for flash will always exist and in many cases the construction of the mold plays a big role in minimizing this potential. However, there are design actions that can be taken that will improve the robustness of the mold, thus decreasing the chances of flash on the part. One major way for avoiding flash is to have "flat-on-flat" contact for the mold seal-off features. Fig. 28 shows how an intersection of 2 holes can be redesigned to reduce the potential of flash using a D-shaped hole as an ideal seal-off surface for the intersecting hole. In this case, two flat surfaces are sealing against one another providing a tool that will be easy to maintain and less likely to generate unacceptable flash during the molding process. The alternative displayed in the figure shows the least attractive approach, which requires one of the cores to have a contoured or profiled face to match the core or hole that it will be sealing against during the injection portion of the molding process. In circumstances like these, the core orientation is critical and the feathered edges are likely to wear more rapidly affecting the shape and size of the molded feature. Mold flash is also a concern in these situations.

Fig. 27

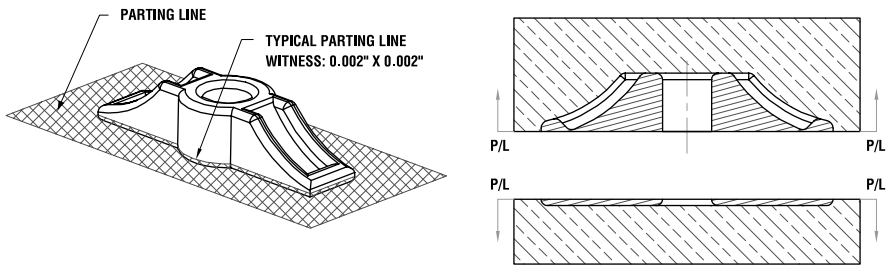
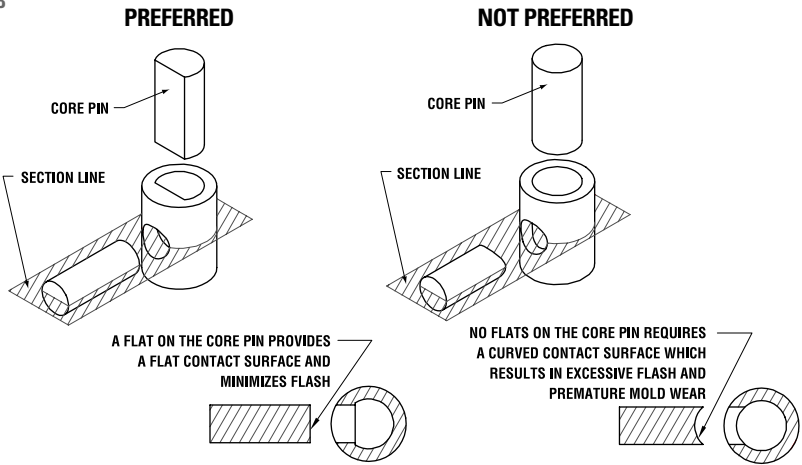
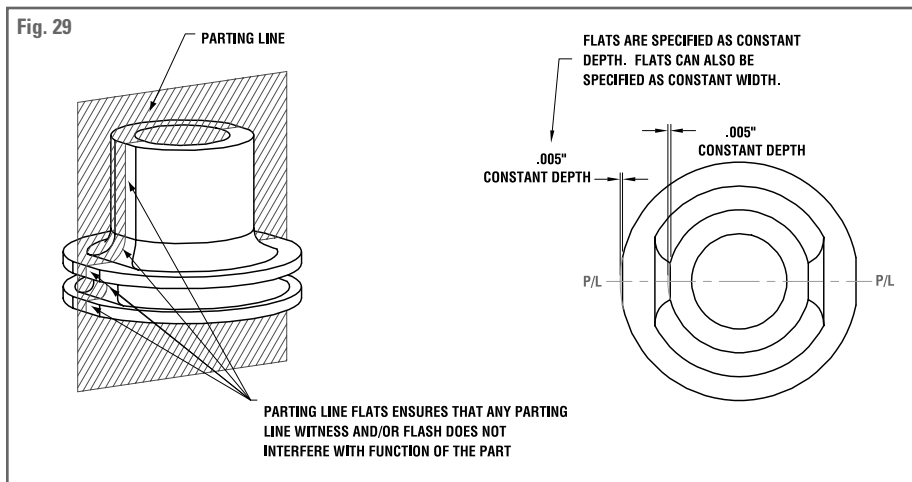


Fig. 28

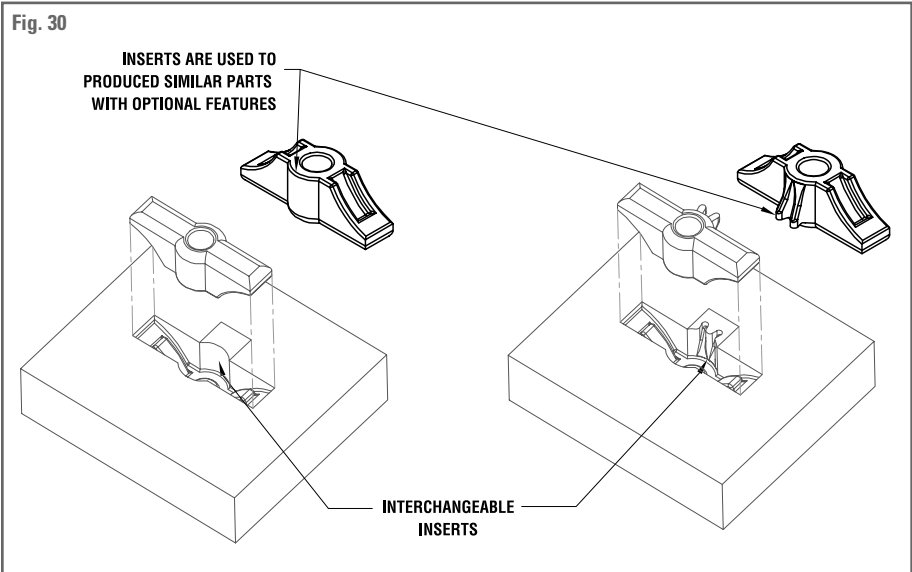
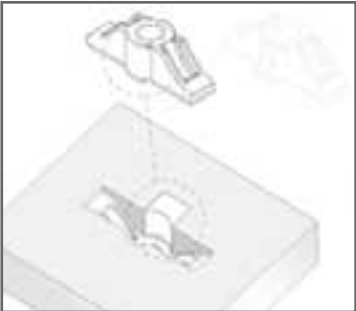


Whenever possible, areas of potential flash and/or witness lines are moved away from critical areas. In the circumstances where this is not possible, there may be alternatives to ensure any witness lines and/or flash does not interfere with the function of the part. Fig. 29 illustrates one of these alternatives. On a cylindrical component with an external undercut, the parting line would run lengthwise, down the center of the part. To avoid a situation where any witness on the O.D. could interfere with the function of the component, small flats are added along the parting line to ensure that any witness line and/or flash would occur below the functional diameter of the part.



Interchangeable Mold Inserts

Multiple parts that have only minor variations between them may be produced using interchangeable mold inserts. All common features are produced by the cavity, but the unique feature is produced with an insert that can be pulled out and replaced with another insert containing an alternative feature. Fig. 30 illustrates a mold with interchangeable inserts to produce 2 different parts. Sharing a common mold and utilizing inserts minimizes the tooling fabrication needed, thus providing tooling cost savings. As with any metal-to-metal seal-off areas, there will be a slight witness mark on the part and this should be taken into consideration during the design stage. It should also be noted that interchangeable inserts can generally be accommodated on low to medium volume parts, but high annual volume applications are normally better served with independent molds for each part design configuration.



Dimensional Tolerances

As a starting basis, MIM is capable of as-sintered tolerances of:

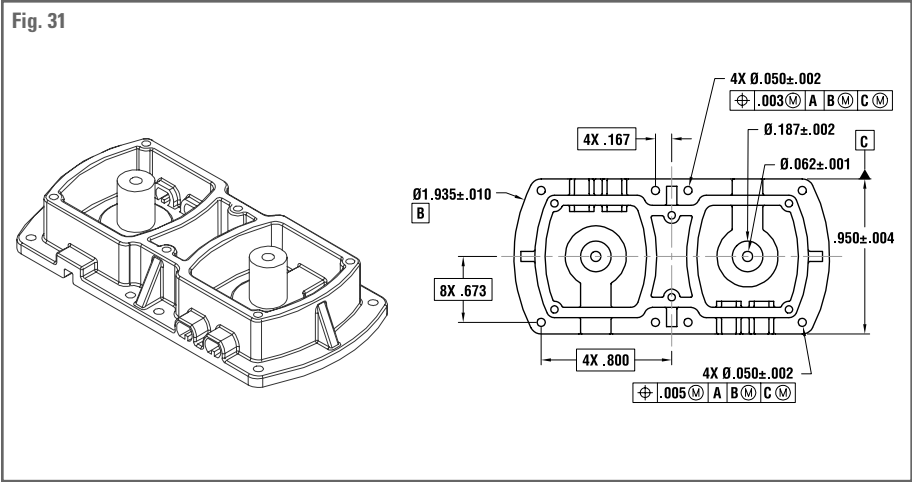
$\pm 0.3\%$ of nominal (i.e. 1.000" ± 0.003 ")

This compares to the investment casting process with tolerances of:

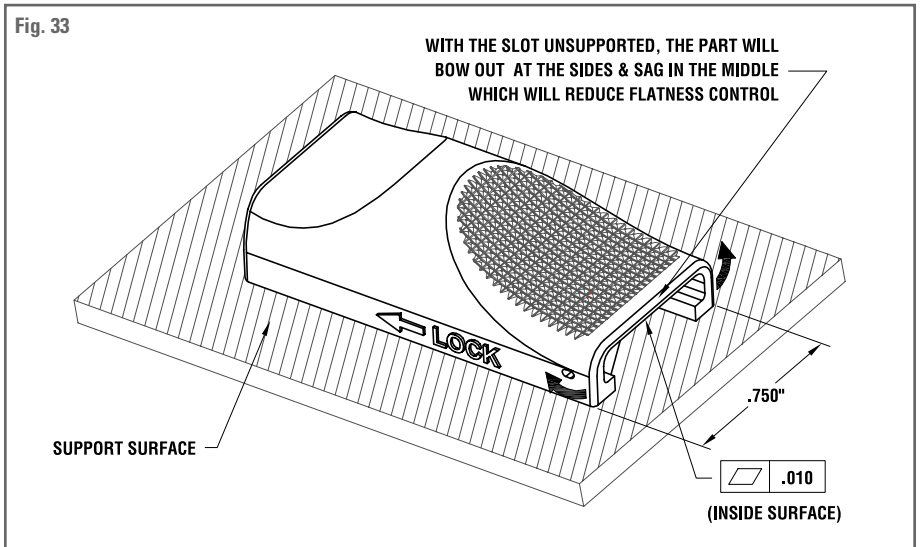
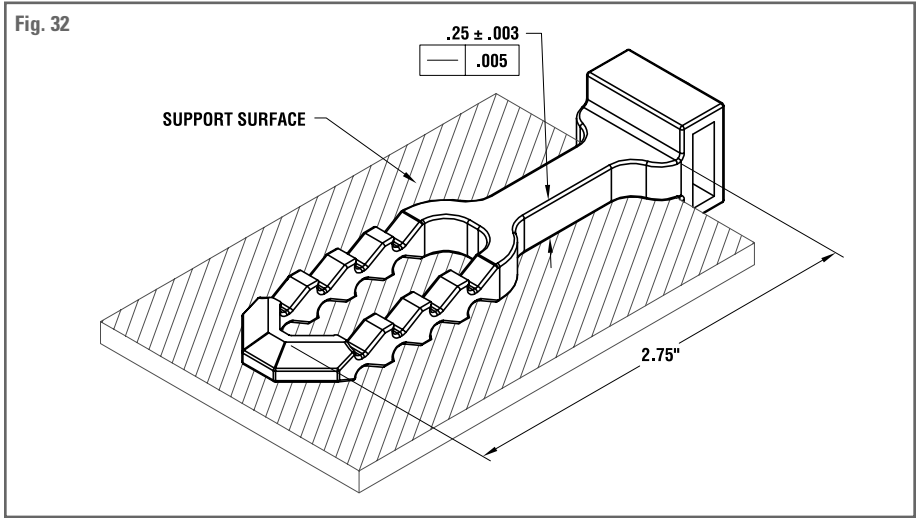
$\pm 0.5\%$ of nominal (i.e. 1.000" ± 0.005 ")

The exact tolerance capability on any feature is influenced by a variety of variables that are inherent in the MIM process. The resulting tolerance capability may be less than the $\pm 0.3\%$ noted above or greater in some cases. Variables such as part design, size, shape, material, gate location, number of cavities, mold construction techniques, annual part volume, and inspection techniques need to be taken into consideration. The material chemistry selected for your application can have a greater effect on tolerances that you might imagine. Not all materials produce the same tolerance results. Gauging or inspection requirements are an integral element of a component design and could have a heavy influence on tolerance capabilities. It has been our experience that theoretical intersections, centers of radii, and very small features require larger percentage tolerances due to gauge resolution, repeatability, and capability limitations. Kinetics' design engineers are available to discuss gauging designs while assisting your component design efforts.

Fig. 31 shows examples of the typical tolerance requirements for a MIM component without the need for any secondary operations.



Depending on component geometry, flatness and straightness specifications of down to .001 inch-per-inch are achievable. This is especially true if the entire critical surface can be supported during debinding and sintering, or the critical feature is perpendicular to the supported surface. Gate location, cross-sectional thickness, and cross-sectional geometry have an effect on the resulting straightness or flatness. Fig. 32 & Fig. 33 show examples of various MIM geometries and the resulting flatness or straightness.



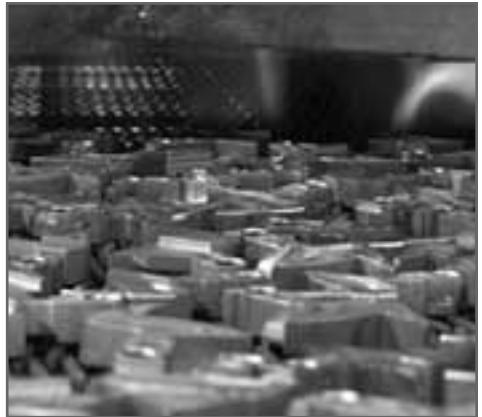
Secondary Operations

To minimize the cost of secondary operations, the general tolerance guidelines in this design guide should be applied. Should a feature require a tighter tolerance than the MIM process can offer, a secondary metalworking operation can be performed. Kinetics' MIM material can be machined, tapped, drilled, broached, sized, ground, or welded like its wrought material counterpart. When annual volume requirements are high enough, Kinetics develops fully automated secondary operations to minimize the part cost of these added process steps.



Heat Treating

Similar to wrought components, MIM components can be heat treated to improve strength, hardness, and wear resistance. Kinetics' MIM materials respond very well to standard heat treatments used on wrought materials. As an example, Kinetics' MIM 4605 material can be heat treated by standard quench & temper, austemper, induction hardening, or case hardening processes. Various material properties are available at Kinetics' website from our home page, and are in a downloadable PDF format. Additionally, the recommended industry standards for the hardness of MIM materials are covered in the MPIF STD 35, which is available from Kinetics upon request.



Surface Finishes & Plating

Kinetics' Metal Injection molding process produces components with densities that are generally equal to or greater than 97% of theoretical wrought material densities. The high densities result in as-sintered surface finishes that are typically 32 $\mu\text{in Ra}$. With the addition of secondary operations such as tumbling, grinding, and polishing, surface finishes better than 16 $\mu\text{in Ra}$ can be achieved. Additional information regarding surface finishes can be found in the "material properties" section of our web site through our home page. Kinetics' MIM materials can be readily plated or surface treated with standard processes used on wrought materials with no need for special surface preparations. Examples of some plating and surface treatments offered are: electroless nickel, chrome, zinc, chromate, nickel Teflon, black oxide, and passivation.





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