Powder Injection Molding in North America – Upbeat Again

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Introduction

While putting together this status report on powder injection molding in North America, the words from Charles Dickens echoed in my mind – "It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, …" The experienced practitioners did not say it quite this way, still these opening lines from *A Tale of Two Cities* probably best condense many conversations into a few words.

This report is on powder injection molding (PIM) in North America, which is dominated by the activities in the USA. It includes custom and captive molders, as well as metal, ceramic, and carbide powder variants. However, this treatment ignores other North American net-shaping techniques that are often included under the label of "metal injection molding" such as aluminum and zinc die casting and magnesium thixomolding.

In the early days of PIM, North America dominated the field. However, in the past few years the landscape in PIM parts consumption and production shifted. Like many other products, North America is moving to a substantial reliance on imports – both PIM parts and assemblies containing PIM parts. But that situation might change since currency exchange rates now make it favorable to invest and produce in North America. Another factor having impact on North America is acceptance of PIM by the automotive industry. Several firms report strong growth in that direction. Indeed, it seems almost everyone in the field has at least one "secret" high production volume project in the works.

To compile this report, a wide cross-section of the industry was interviewed. Those conversations repeatedly spoke of recent industry retrenchment, repositioning, but now solid growth prospects. Those companies surviving the economic slow-down are now very conservative. Meanwhile, as PIM firms are purchased by investors the culture is changing from the former technology focus to a financial emphasis.

What Happened in 2006?

PIM in North America has been slowly concentrating into the hands of about 80 molders and 30 key suppliers (feedstock, powder, equipment). Almost all of the firms with sales exceeding $1 million per year have been in business for several years. This means they have successfully weathered the business cycles. Within the industry the most recent down cycle was labeled as “horrible”, yet the core industry is now positioned for rapid growth. That growth has stared and will become evident over the next year. A few firms reported excellent recent growth, reflective of the specific markets more than the general situation. Because of the low dollar value compared to other currencies, 2006 was a good year for equipment exports, even though domestic equipment demand was soft. Thus, the current capacity expansion is taking place with an established equipment infrastructure.

During the sales slow-down, many of the North American PIM operations took on longer-range projects that now are coming to fruition. As always, there was a conflict of customers seeking quick turn-around on sample parts, yet those same customers took long times to reach buying decisions. In one case it took eight years for an automotive project to reach production. During 2006 the best news came from new orders in medical, defense, firearms, and industrial applications. Many of these should run for many years, providing future stability for the custom molders and their suppliers. A very positive factor is the widespread anticipation of new automotive parts that will reach into the millions per year rates. This contrasts with the 2006 situation where production quantities averaged less than 200,000 per year. An often mentioned problem has been in keeping large volume jobs running; apparently once a project is booked the purchasing team steps in looking to reduce cost. The hand-off from engineering to purchasing has been a precursor of difficult times for the custom molders.

What is Happening Now?

North American PIM is moving forward again, with many enquiries and even large orders. The growth is not strong yet, but the discussions in 2007 provide favorable outlooks for future years. However, as things are picking up there is realization that some basic knowledge has been lost due to corporate downsizing. Moreover, industry ownership changes have defused the former positive spirit. In the past few years these changes have included Britt, Ferro, Hawk, Howmet, Kinetics, Lake Erie Design, MedSource, Parmatech, Quest Technology, and Remington Arms. It is rumored that up to five more PIM operations are up for sale. Meanwhile, some of the leaders, such as Kinetics, Parmatech, and PCC Advanced Forming Technology have been rationalizing customers, market segments, production efficiencies, and generally making big, but expensive steps focused on the next wave of industry growth.

Some growth is taking place via new PIM firms, but these are all very small and only add to the number of industry participants, but do not significantly impact sales. Most of the new entrants are regional custom plastic molders taking advantage of support from feedstock and equipment providers, although one start-up is taking place inside a large corporation. In the past year, at least four plastics firms and one traditional powder metallurgy press-sinter firm have moved into PIM.

Medical applications have become one of the largest metal PIM application areas in North America. This is very evident by the number of booths at medical device exhibitions. So the industry is busy again, seeing steady but slow growth, and has learned to be conservative based on recent sales dynamics. Probably 75% of the firms will grow this year.

Future

But the big news is probably next year when several of the larger firms expect to each add as much as $10 million in automotive component production. Often such forecasts generate false expectations, because several different firms plan on landing the same large order. Also, several industry experts were cautious since the new parts have tolerances that are tighter than current capabilities. Unfortunately, post-sintering coining may be too costly. As one expert said, “If you handle the part after sintering, then it will go to Asia.” Today, customers are asking for more complexity, tighter tolerances, and more that just parts. These requests are often outsize the comfort zone for the traditional molder and require significant innovations in secondary operations.

The potential of several automotive orders makes the industry upbeat. In recent years smaller customers were slow to change designs, so some of the past PIM products have run for several years. Now many of the PIM firms are strategically targeting these projects to help dampen sales cycles. Automotive projects are everywhere. Also some of the projects that moved to Asia are returning to the USA. With the current healthy pipeline of requests for quotation (many are projected at much larger quantities than seen in the recent past) and favorable currency situation, PIM in North America should do well next year. There is growth, a good pipeline of requests, expanding applications, and projects targeted at reaching 20 million parts per year. To secure these projects, the older PIM firms realize that leaner, faster, and cheaper are required, so they are looking how to shorten lead times and operate with thinner inventories.

Statistics

Today, North American PIM is in the hands about 80 commercial operations with about 10 additional pilot efforts. These firms should deliver more than $300 million in PIM sales for the current year.[*] About one-third of the firms are producing parts for internal use. Curiously, internal operations account for 45% of the industry product value and are dominated by ceramic firms. For comparison, in 1997 there were 126 firms giving $190 million in sales in North America. By 2003 North American PIM sales had slipped to $177 million. Thus, 2007 will represent both concentration (fewer actors) and significant sales gain for PIM. So far, only Mathson Industries has announced a new plant.

About 60% of the PIM firms focus on metals, 34% on ceramics, and 6% on carbides. Sales of cemented carbides by PIM are much higher per unit mass or per item, but typically the production volumes are low. Often cemented carbides are produced with low-pressure molding machines. Up to recently, carbide applications were not growing beyond niche applications. Meanwhile the metallic applications have the strongest near-term growth prospects. Some of the

[*] During the first half of 2007, various guesses have been made on the global PIM market. These range near $900 million. Based on powder shipments, trade press, and financial documents, the estimate used here is a global PIM market from $835 to $900 million for 2007. North America’s portion is estimated at $300 to $315 million, and metallic PIM in North America then is estimated to range from $180 to $190 million for 2007.

largest molding operations are ceramic firms where the PIM product is for internal use, with casting cores being a prime example.

In North America, the PIM largest operations range up to 35 molding machines. This is similar to the size of the largest off-shore firms. Sintering technology is split between batch furnaces and continuous furnaces, with new continuous furnace installations taking place to support the upcoming automotive campaigns. However, batch furnaces are still very popular, especially at the smaller firms.

There is no single trade association focused on PIM in North America. The Cemented Carbide Producers Association has 15 members, and 4 of those practice PIM in North America. The Ceramic Manufactures Association represents 47 firms, mostly from the USA, but only a few member firms offer PIM services. The Metal Injection Molding Association consists of 31 firms, 15 of which are North American molders.

The estimated $300 million PIM sales in North America for 2007 will be performed by about 90 firms (including 10 pilot operations). Although widely varied, a simple division of sales by firms suggests an average operation with $3.3 million in annual sales. The workforce is estimated at near 1800 full-time equivalent personnel. This gives the average employment per PIM firm at just 20 people with annual sales per employee near $170,000. With slightly over 300 active molding machines, the industry is averaging near $1 million in sales per molding machine per year. However, about 20% of the industry is significantly under-using installed capacity. On the other hand, one production operation will ship about 80 million parts in 2007.

The PIM R&D personnel count is about 60 people, split between consultants, government workers, graduate students, research faculty, and industrial experts. This is probably equivalent to fewer than 40 full-time people. As a collective body, this R&D community produces about 24 archival journal articles and 5 patents per year while making near 40 conference presentations per year. This North American PIM R&D group is anticipating the addition of nearly $2 million in new equipment during 2007. The two high output academic programs are at Oregon State University and Mississippi State University, with some efforts at San Diego State University, the University of Missouri – Rolla, and Penn State University. National laboratory efforts are in progress at Los Alamos (beryllium), Sandia (ceramics), and Pacific Northwest (titanium).

Market and Application

Figure 1 shows a pie chart of the North American PIM market partition for 2006.

Ceramic molding was initiated in the 1930s and today ceramic cores for aerospace castings is the largest application for PIM in North America, accounting for 23% of the total commercial value (dollars not tons). Other aerospace applications include a small amount of metallic materials, including superalloys. Medical and dental applications based on metal and ceramic PIM account for 24% of the PIM market; indeed, metal orthodontic brackets are one of the long-running successes for metals. However, the first white and semi-transparent ceramic brackets are arriving. The impact will be to slowly reduce the metallic bracket sales, but they will give a substantial increase to sales since the ceramics brackets are more costly. Historically, in spite of early successes in the 1980s, automotive applications remained small at about 5% of sales. But that is changing rapidly and will exceed 10% for 2007. Industrial applications, especially components for valves, fittings, hand tools, and similar objects, amount to almost 18% of current sales.

Firearm and military applications are holding steady at 11% of sales and should remain strong. Wear components, often from carbides and tool steels or hardenable stainless steels, are a stable area at 9% of sales. Materials Processing International is moving aggressively into an array of complex-shaped carbides for nuclear, aerospace, oil and gas, and other areas where PIM has not normally seen. Electronic components, especially specialty hybrid packages, transducers, and sensors, are 6% of the sales. Business machine components have almost disappeared along with the demise of mechanical typewriters, postage machines, and similar devices, reflecting a shift to electronic devices fabricated in Asia. One of the new growth areas is thermal management materials. After 15 years of incubation, finally PIM heat sinks, cooling packages, and computer mounts are gaining significant attention.

Up to now there is has been no concerted effort to market PIM in North America. One positive step this year will be to include metal powder injection molding on the www.pmdatabase.com web site. However, that site has just 200 visits per month and is mostly devoted to ferrous press-sinter powder metallurgy data. Since fewer than half of the web site visits are from North America and only a third are from users, it is doubtful that inclusion of metal powder injection molded products in that database will have much impact.

Geographic Distributions

The North American market shows no evidence of PIM in Mexico and only three operations are in Canada. There is one feedstock supplier setting up in the Caribbean. Thus, in large part PIM North America is concentrated in the USA.

The geographic distribution of PIM is shown in Figure 2. In this nomenclature:

> **Midwest** = Ohio, Michigan, Missouri, Minnesota, Wisconsin, Ontario;
>
> **Northeast** = New Jersey, New York, Massachusetts, New Hampshire, Connecticut, Pennsylvania, Maryland, Quebec;
>
> **West** = California, Oregon, Colorado, Idaho, and British Columbia;
>
> **South** = Texas, Tennessee, Florida, Georgia, Kentucky, South Carolina, North Carolina.

The other states or providences have no detectable commercial activities.

The largest number of firms is in the Northeast, yet the South and West dominate sales. The South is home to captive ceramic operations and the West has some of the longer running actors, such as Form Physics, Injectamax, Kinetics, Ortho Organizers, Parmatech, PCC Advanced Forming Technology, Polyalloys, Quest Ceradyne, Rocky Mountain Orthodontics, Small Precision Tools, World Class Technology, Wunder Mold, and Unitek 3M.

Materials

Most of the evolution of new materials for PIM is ending. Powder producers, such as ACuPowder, AMETEK, BASF, Carpenter Anval, Hoeganaes, International Specialty Products, Sandvik Osprey, SCM Metal Products - Atmix, USBronze, and Ultrafine Powder Technology, claim about 200 alloys are in current production. These include several austenitic, martensitic, and ferritic stainless steels, some heat treatable steels, and an array of special alloy. Most customers are satisfied with available metals and oxide ceramics, especially with the recent addition of hardenable stainless steels and heat treatable ferrous alloys. New additions include standard microelectronic packaging alloys for glass-metal sealing (Fe-29Ni-17Co) and low thermal expansion coefficients (Fe-36Ni). New tungsten-copper powders have opened up low thermal expansion and high thermal conductivity applications, and surprisingly pure copper has been introduced in several computer components. Also, superalloys have reached production status.

Titanium is the subject of much speculation and promise, but not significant sales. In spite of government funded efforts to evolve low-cost titanium powders, and by implication PIM powders, today most of the available powders are the old standby sponge fines and hydride-dehydride variants. Some of the companies reportedly developing new powders include DuPont, Honeywell, International Titanium Powders, and Materials and Electrochemical Research. Recent pricing showed the lowest cost PIM grade titanium powders were in the $40/kg range. This price is too high considering the impurity levels which deny use for demanding applications. There is concern that after several years and much investment, PIM titanium is still unable to overcome the cost barrier. Hence, low-cost titanium looks like it will continue to remain the “material of the future.” Even so, several firms have small efforts in this area to be prepared should one of the novel powder fabrication processes deliver on the cost-purity targets.

Feedstock suppliers, such as Advanced Metalworking Practices, BASF, and Ryer work with PIM firms to formulate new custom mixtures. In this regard, there are efforts to develop niche materials, such as new carbides, nitrides, and other hard materials. Transparent alumina is a favorite in the lighting industry for sodium-mercury vapor lamps and in the orthodontic industry for invisible brackets. Alloys for electronic packaging (for glass to metal sealing and heat dissipation) are a niche that keeps growing, especially with applications in gasoline-electric hybrid vehicles, high-end gaming computers, home servers, and military electronics. Other materials moving into production include an expanded array of tool steels, nickel-base magnetic alloys, nickel-base superalloys, and precious metals (gold and silver based). HJE reports that the high cost of precious metals has shifted the business model to toll molding, a new twist for PIM.

A set of property standards for metallic materials was issued by the Metal Powder Industries Federation in 2007, bringing the total coverage to 11 alloys, two of which are listed in both the as-sintered and heat treated conditions. New testing standards by this same body have come out for corrosion, density, tensile, and impact test procedures.

Strategic Moves

One of the unanticipated threats to North American PIM might come from the new owners-investors. Their drive for financial performance can seriously undercut technology and the solution to critical problems such as improved tolerances. Further, the currency exchange rate might bring in the next wave of investors from off-shore competitors looking to purchase a toehold in North America. Another concern is the slow customer acceptance process that is common in the litigation-rich US.

One of the strategic needs for PIM is to greatly accelerate first article production, primarily via faster acquisition of feedstock and tooling. There is substantial opportunity for differentiation between firms and technologies using time compression, especially when being compared with off-shore sources. Further, improved tolerances are needed, mostly to minimize expensive secondary operations. Labor costs hinder many of the high volume PIM projects from using North American sources. So the near-term focus needs to be on time compression and improved tolerances. In that regard, current computer simulation techniques for PIM tool design, molding cycle design, debinding and sintering cycle optimization, with predictions of final size and shape, are of great value. There are three commercial packages for mold filling simulation, but only one is integrated through sintering to predict final size and shape. At Mississippi State University we have been teaching students how to use the fully integrated package from CetaTech which gives three-dimensional simulations of molding and sintering, including determination of powder-binder separation. Figure 3 shows some outputs for the simulation as applied to a copper fitting. It was gated on the lower shoulder and the four plots show the velocity contours, filling time, average temperature, and pressure with weld line location. This package is in use at several sites in the USA. Other computer modeling efforts are at the verification stage.

Future Prospects

The traditional ferrous powder metallurgy field has been undergoing contraction in North America as automotive production becomes global. Based on recent evidence, predictions of rapid PIM market growth seem to have reasonable credence, but the partition of that growth in North America versus the rest of the world is probably yet to be determined. Rapid growth, in the 20 to 30% per year range, took pace in the USA during the early years of PIM, but that growth stumbled and is only now showing recovery. During the recent industry retrenchment, the off-shore firms gained traction. The response from the North America PIM operations must come via use of contemporary management tools that involve lean manufacturing and reduced defects. North American firms need to find combinations of quality and technology to clearly differentiate themselves from low-cost manufacturing sites in Asia. Thus, a few firms are examining options such as having management, product development, engineering, and marketing in the North America, while moving production to Asia.

Meanwhile, the past few years have provided an education for PIM on how to cater to difficult and large customers, and how to weather large purchasing swings. Curiously, some of the larger North America purchasers of PIM parts (for example Apple, Hewlett-Packard, Seagate, and Motorola) seem to reject domestic fabrication. These same firms expect North America residents to buy their products, but they shun domestic content. Labor cost drives assembly and parts production to Asia, but that same labor cost provides consumers with the wealth need to buy these same products. With an inability to penetrate the consumer applications, the North

American PIM industry moved to smaller projects in the medical, defense, firearms, and aerospace fields.

Technology Support – Research for Economic Development

Only a few North American partners remain to support the research, testing, and education needs of the industry. Survival has forced these programs to focus on economic development with mandatory industrial participation. Accordingly, program output is now measured by patents and job creation, not papers and presentations. A further reduction has come about due to the decline in funding for structural ceramics. The remaining university efforts are focused on new materials (such as titanium, silicon nitride, and composites), computer simulations, microdevices, and novel powder-polymer technologies such as extrusion.

All of this begs the question on how to integrate, market, and revive North American PIM as new growth opportunities arise. Many views exist. My personal perspective is that PIM firms will partner with foreign manufacturers for some projects while creating differentiation via increased investment in technology and marketing. Key gains can be derived from tighter tolerances, leaner operations, and shorter times to first components. In this regard, computer simulations reaching commercial status will be important tools for the PIM community.

Acknowledgements

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Figure 1. This pie chart gives the approximate partition of applications for PIM in North America for 2007.

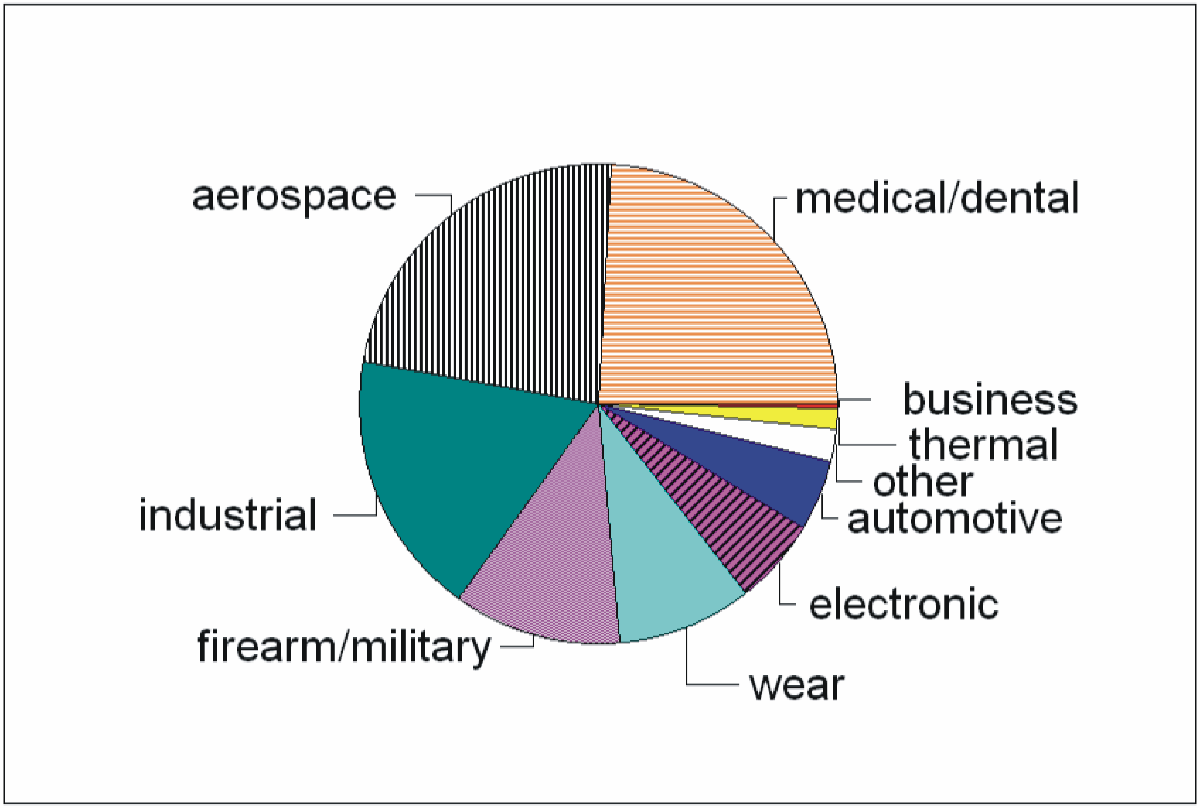


Figure 2. The geographic distribution of PIM in North America based on four similar sized population groupings, both in terms of sales and number of firms.

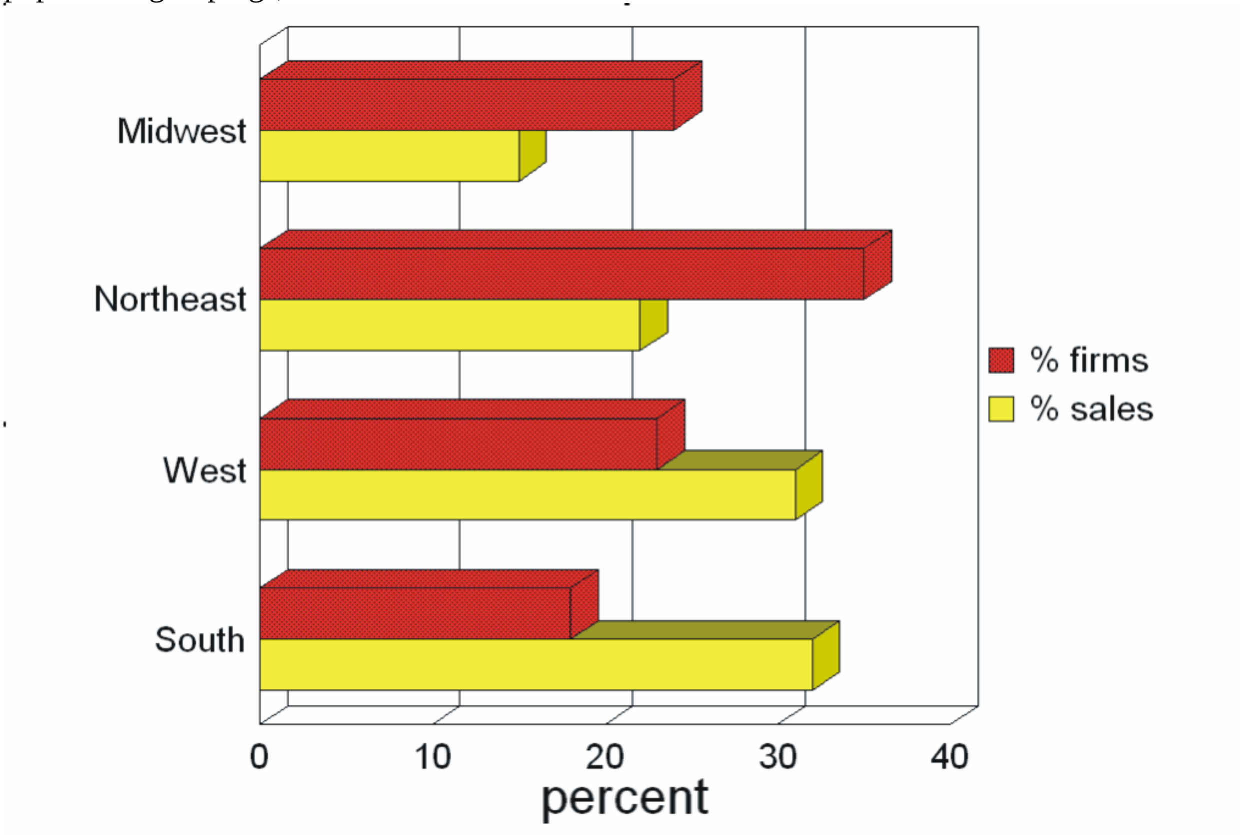
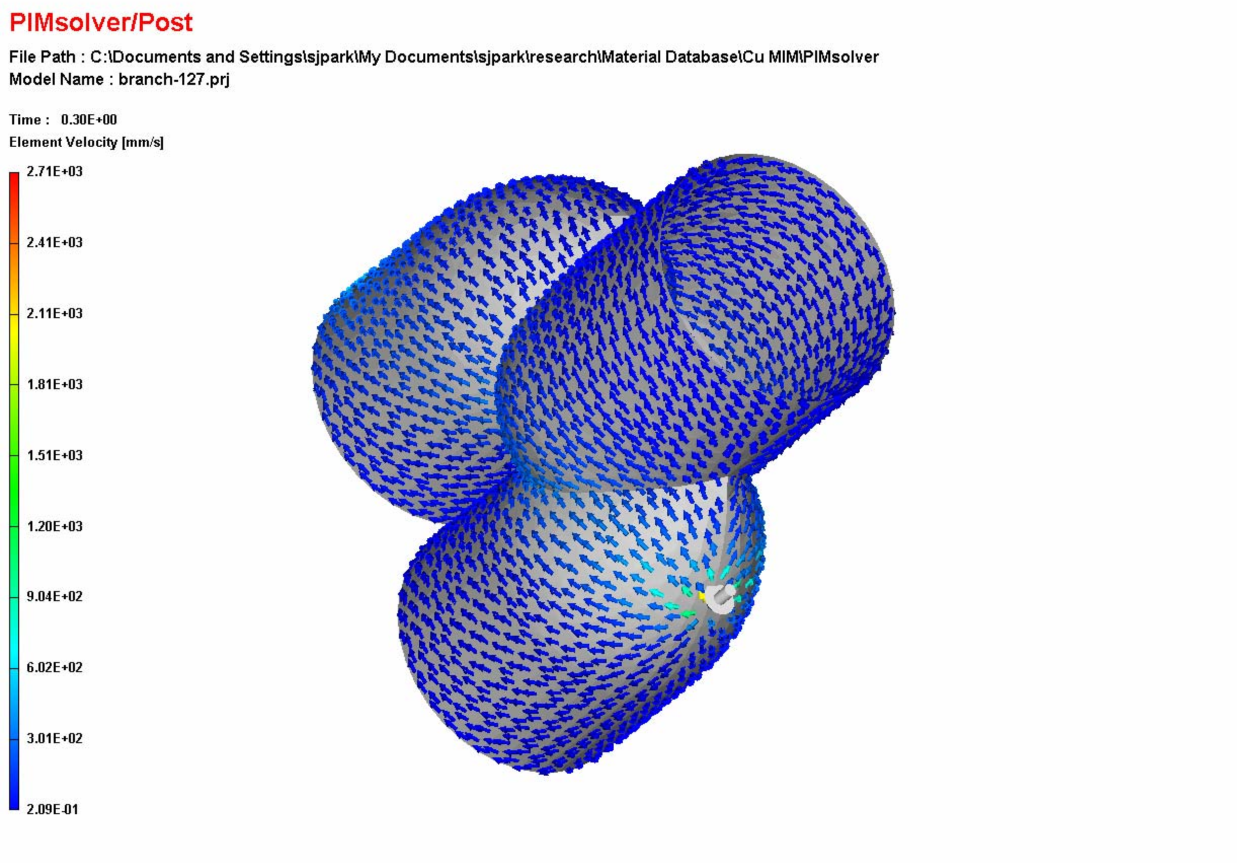
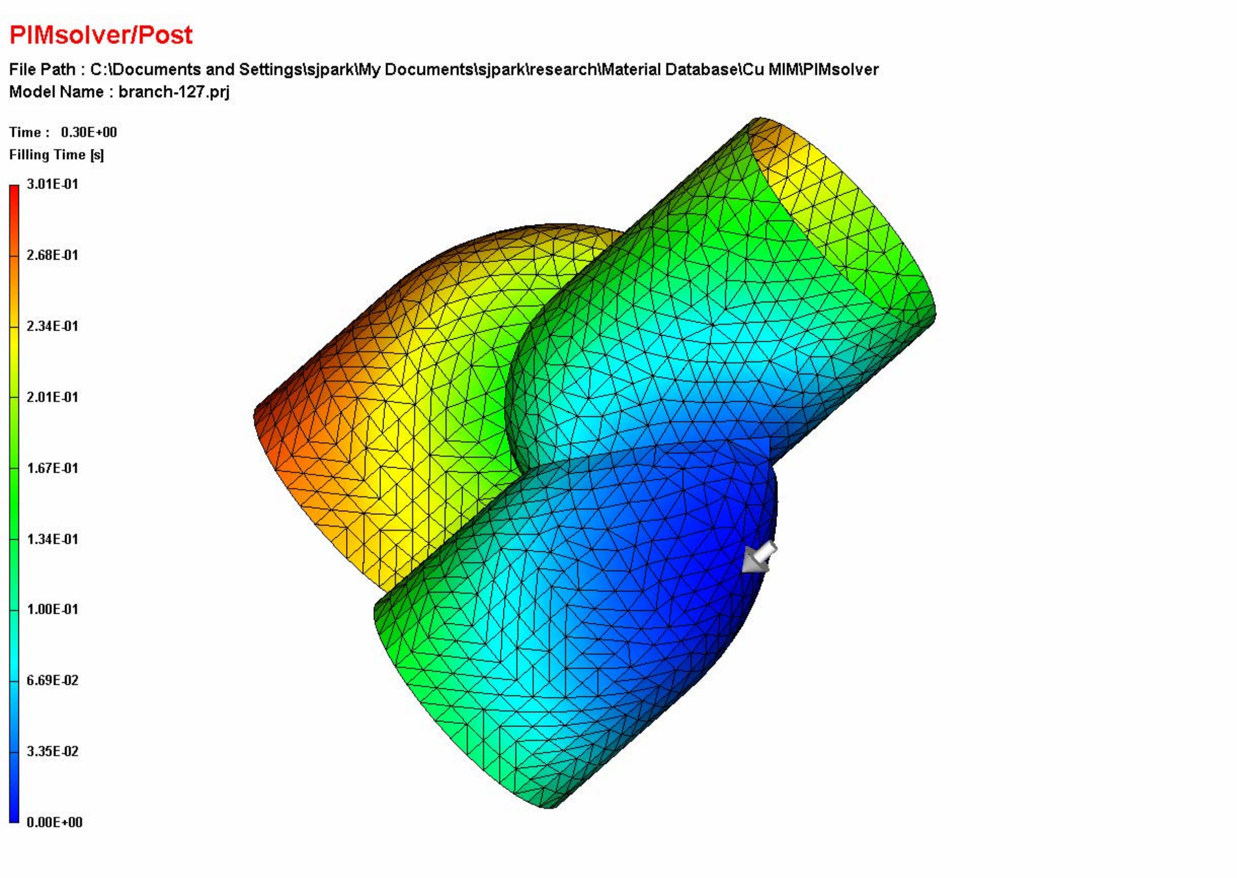


Figure 3. Full three-dimensional computer simulations of the molding process for molding a hollow copper fitting as performed using PIMSolver from CetaTech, showing a) velocity contours, b) filling time, c) average temperature, and d) pressure distribution with the weld line indicated (images courtesy of Seong Jin Park and Young-Sam Kwon).

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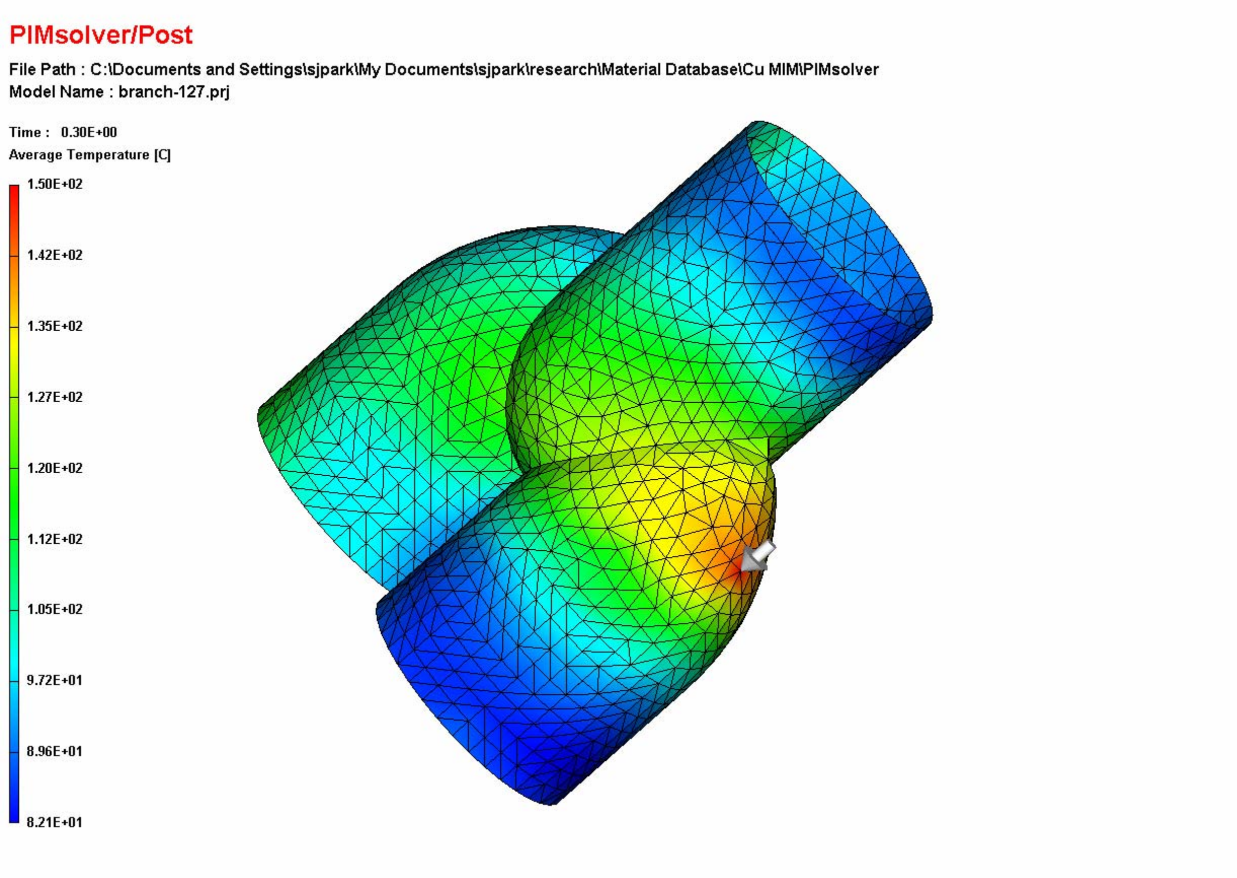
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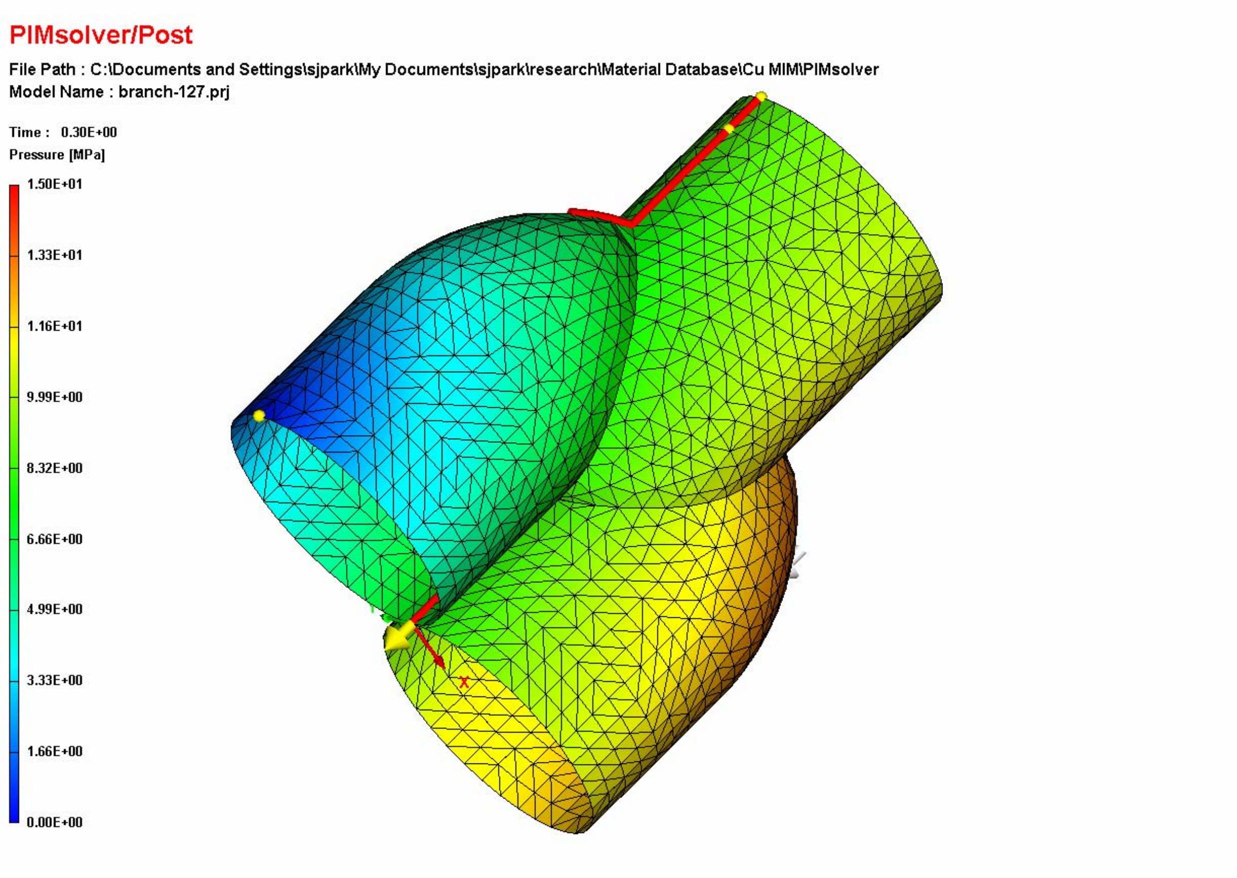
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Figure 4. Picture of the molded copper fitting.