Metal and plastic moulding – a happy relationship

Greg Goto, senior project engineer at Parmatech Corporation, describes how metal and plastic injection moulding can work in harmony, with the replacement of a plastic gear part with stainless steel using a powder metallurgy process.

A major medical instrument maker was looking for improved strength without the high cost of machining for an articulation gear part that had originally been designed in plastic. He found a solution in a metal injection moulding (MIM) technology that produced a 17-4 stainless steel part that had improved mechanical strength over plastic, and was also precise enough for secondary plastic insert moulding.

Historically, MIM products have not been consistent enough to insert mould without running the risk of ruining the insert moulder's tool. The successful approach used here can hold extremely tight tolerances, involve no secondary operations, and reduce costs by as much as 50% over machining a similar part. For those looking for more strength than their plastic can give them, MIM parts insert moulded with plastic can be an extremely cost-effective solution.

Articulation gear part

Parmatech Corporation was first approached by the medical instrument manufacturer regarding an articulation gear part in an instrument primarily used for minimally invasive surgical operations. The component was designed to be polymer injection moulded, but during trials and development, the articulation gear would strip due to the forces involved. At the far end of the instrument's articulation portion, the part has to lock in at a very specific angle, and it was snapping back and not holding. Figure 1 shows the orientation of the articulation gear and where it sits in the device.

Machined aluminium was sufficiently strong to prevent stripping of the gear teeth, but the subsequent cost to machine was a significant departure from planned costs. The manufacturer approached Parmatech to determine if this component could be suitably transitioned from machined aluminium to MIM stainless steel.

Since it was already in late stage development trials, the instrument manufacturer had temporarily switched to an aluminium machined part to be able to continue production without delay. The machined part was then insert moulded with plastic.

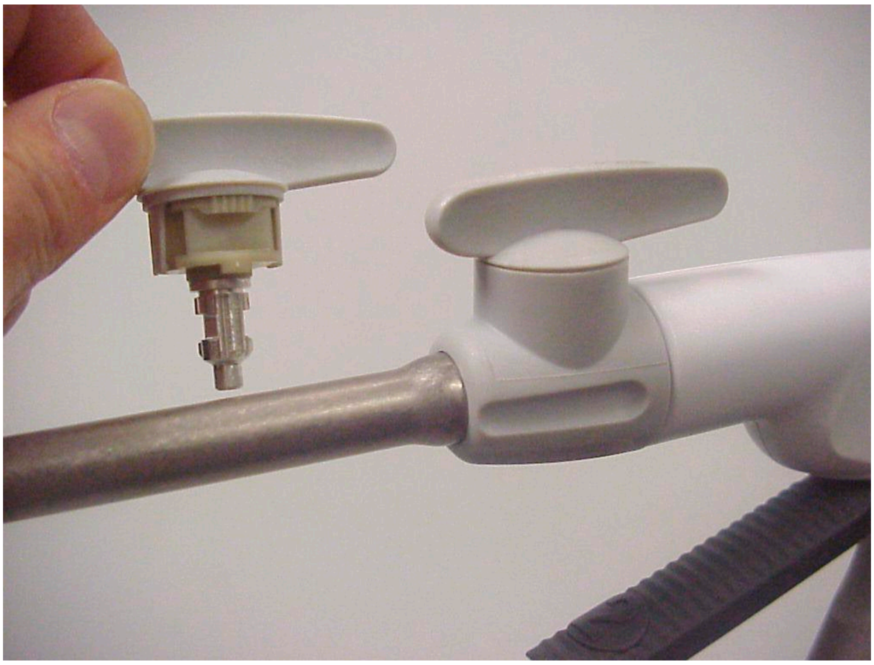

Figure 1. Articulation Gear.

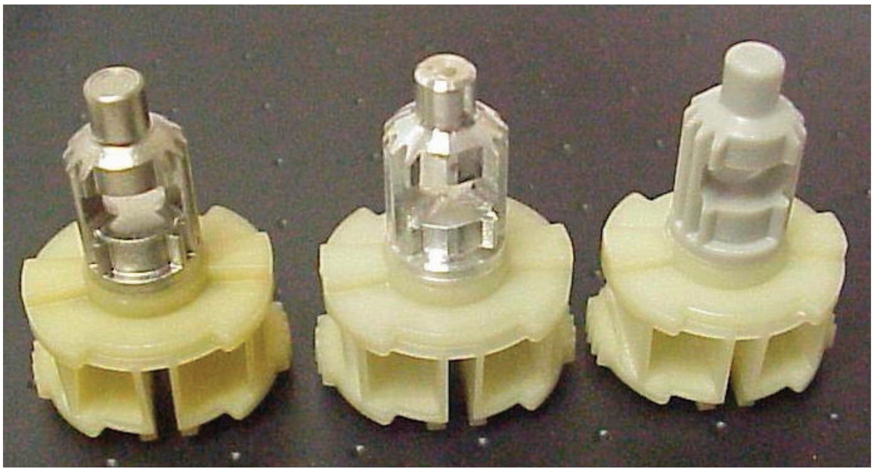

Figure 2. Articulation gear evolution.

The manufacturer launched the product with the more expensive machined component, and then sought to convert the machined component to a MIM part. This sequence is a relatively common occurrence in the MIM industry, as customers who can successfully convert to the MIM process can cut the price in half over machined components.

Twist in the tale

As common as it is to look for MIM for cost reduction over machining, the story has a unique twist. The part is insert moulded, a process in which tolerances are typically accurate to within .0005 of an inch. Historically, plastic moulders have been hesitant to use MIM parts for insert moulding, because the tolerances are so tight that if the MIM part's dimensions miss any tolerance, the insert moulder's tools could be destroyed.

In this case, the instrument manufacturer asked the insert moulder to work with Parmatech to use a MIM part, rather than the machined part they might have ordinarily preferred to ensure the proper tolerances and protect their tool from the dangers of crashing. Although initially hesitant, the insert moulder agreed to try the process, since the cost argument was so compelling. The insert moulder's agreement to use the MIM part gave Parmatech the opportunity to use its proprietary MIM process with insert moulding for the first time.

Figure 2 shows the different materials used in the articulation gear during the course of its development. On the far left is the MIM part's 17-4 stainless steel. In the middle is the aluminium machined part, and on the far right is the original plastic moulded part. All parts are shown after the insert moulding of the part in plastic.

Material selection

Since the manufacturer had already determined that machined aluminium should meet the part's primary mechanical requirement for gear teeth strength, Parmatech had a large selection of alloys from which to choose for the MIM process. One of the most commonly used alloys, MIM-stainless steel 17-4, was chosen due its low material cost, robust operating parameters, and extensive operational history in terms of as-sintered tolerance capability.

Parmatech made the 17-4 stainless steel articulation gear part with its proprietary MIM process, and then sent the part to the insert moulding company, which put the part into the mould, sealed it and injected the insert moulding. The two pieces, now joined together, were sent to the manufacturer for assembly into the instrument. The 17-4 material used for the gear is corrosion resistant, high strength, and hardenable. The process is typically at least half the cost of machining a similar part, depending upon the complexity. In this case, each of the gear teeth and the hole in the middle of the gear had to be individually machined. With MIM, this was accomplished with the mould, using no secondary operations.

Meeting plastic insert moulding challenges

After the strength requirement was solved with MIM-17-4, the next focus was on the plastic insert moulding operation. MIM process variation can induce a +/-0.003-inch tolerance on a 1.000-inch dimension, so planning to put a MIM part into a hard tool steel mould, and have it properly shut off to prevent flash or tool damage, is a challenging exercise. Would the MIM part variation exceed the insert mould tool's steel dimensions?

To ensure success, Parmatech worked closely with the insert mould tool builder to precisely determine available space as well as tolerance requirements. The

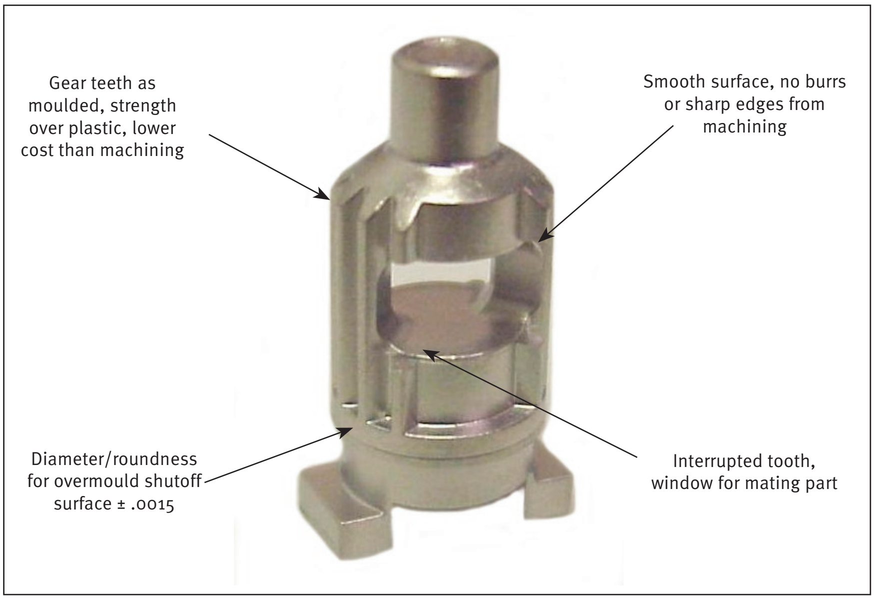

Figure 3. Key characteristics of MIM articulation gear.

Figure 4. The medical instrument is intended for minimally invasive surgery.

critical portion of Parmatech's sintering was to make sure the part's feet have a certain pocket or envelope that must fit exactly. It was absolutely imperative that they be kept within this envelope – missing just one part risked crashing the insert moulder's tool.

Given the known tool steel dimensions of the insert mould, it was determined that the MIM part had to hold a certain geometric tolerance of the feet area, as well as part tolerance on the critical shut off diameter. Parmatech carefully conducted capability studies to demonstrate that the shut off diameter could be held sufficiently to allow for effective shut off and insert mould processing.

The seal around the bottom portion (where the metal meets the insert moulded part) must be shut off so that insert moulding process works properly. The critical dimension is the height and diameter requirements to position it correctly so when the mould is closed over the hole that the MIM part fits in, it is properly sealed so the insert moulders can fill the rest of product with plastic. It must be tight enough, but with no metal-to-metal hard contact to wear out the surface.

Since the diameter getting shut off is not a mechanical one, it did not need too much mechanical strength, just enough to hold plastic flow. Parmatech was able to hold the diameter in roundness to a very tight control using its proprietary processing technology and sintering support. Two years into production, the roundness is still being held to 0.0012 inch and the critical height maintaining greater than 2.00 Process Capability (Cpk). Figure 3 shows the key characteristics of the articulation gear produced by Parmatech for the project.

The project definitely involved challenges. For example, the roundness of the shut off diameter surface needed to be held to <0.003-inch. This was done by repositioning the gate from the original location in the plastic part to an area more symmetric to the diameter, even though it added complexity to the mould design. This helped mould flow uniformity around the area of the shut off diameter. Gravity effects were negligible in the sintering of the part and sagger drag was isolated and did not affect the critical diameter. A sizing operation was prepared in case the as-sintered MIM tolerance was not capable, but its use was ultimately deemed unnecessary.

Other challenges included stable processing and quality of the gear teeth. In order to improve processing capability, a custom setter was designed in order to minimize sagger drag. Parmatech also put considerable efforts in tool design to minimize the effect of interrupted gear teeth shut offs.

Three-way design review

A key to the success of the project was a three-way design process, a multi-company effort that involved interfacing among the manufacturer, Parmatech, and the plastic insert moulding company. The complexity of the design and shape meant it was not possible to make one mould containing all the required openings and features. Every single feature in the instrument has another mating device that goes through it. The handle contains extremely tight tolerances for the variety of different features on the instrument.

The face-to-face design review between Parmatech, the end customer, and the plastic insert moulding supplier helped the parties identify insert mould design and input requirements for the MIM part, ultimately leading to the successful completion of the project.

Parts requiring strength

At the end of the project, the manufacturer received an insert moulded MIM part that met their functional and cost requirements. Component production continues today with no change in processing since the product launch, and the device is performing in the field as intended. The instrument manufacturer has since launched additional products using Parmatech's process, based on the positive experience and value added in this case study.

The success of the project definitely shows that MIM can be used to increase part strength without the high cost of machining, even when insert moulding operations are involved. Cost savings were substantial over the machined part, with no individual part handling occurring after the initial stack at moulding.

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In addition, there is a much higher production rate capability with injection moulding compared to machining. MIM material strength meets application requirements, and MIM material surface finish on the gear teeth was superior to that of machining. There was very little material waste in fabricating the parts versus machining and no secondary operations involved with burr removal like those needed in machining.

MIM parts insert moulded with plastic can be an extremely cost effective solution for those who need more part strength than plastic gives them. MIM parts can even usually be substituted without having to retool the insert moulder if there is one area that needs strengthening.

About the author

Greg Goto, senior project engineer at Parmatech since 1996, has been instrumental in product development and has successfully launched over100 MIM products at Parmatech, including four which received the MPIF Grand Prize award for Design Excellence. He has a materials science background and working history with PG&E, Hitachi Powder Metal, and Carpenter Technology.