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Original

A New Direction in Plastic Air Intake Manifolds

by

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The Plastic Air Intake Manifold (AIM) has become widely accepted since its initial development in the 1980's. Nylon has been the material of choice for these applications. Currently nylon is used in 80% of all AIM's in production. Nylon AIM's have become the material of choice for all high volume production cars. Only limited volume specialty cars continue to use Aluminum AIM's.

The Original Choice:
The first Nylon AIM's were made using the lost core process. This process closely replicates the sand casting process in metals. First a core is made out of a low melting temperature metal alloy. Next it is placed into the injection molding tool. Then the nylon AIM is molded around the core. Finally, the AIM and core are placed into an oil bath and the core is melted out.

The metal alloy cores have a melt temperature of about 200°C. While the oil bathes used to melt the alloy cores are usually run at a temperature of 220°C to 240°C. These temperatures have made nylon 66 with 30% to 35% glass fiber the material of choice for these applications.

The lost core process allows the parts to have excellent design freedom. Any AIM that

Revised by Jan Niehaus, Communication by Design

Polyamide Air Intake Manifolds:

Compare Your Manufacturing Options

by

Charles Taylor, Solutia, Inc.

Abstract

As new technology emerges, manufacturing processes evolve that reduce capital and production costs, while increasing the performance of air intake manifolds (AIMs). This paper discusses the processes available today for the production of polyamide AIMs and the comparative advantages and disadvantages associated with each.

Introduction

Eighty percent of all air intake manifolds in production today are made of polyamide resin. Since the 1970s and 80s, when polyamide AIMs were developed, nylon has become the material of choice for AIMs in high-volume-production cars. Only limited-volume, specialty cars still use aluminum AIMs.

Three different methods of manufacturing polyamide AIMs are in use today:

- Lost Core
- Vibration Welding
- Adhesive Bonding

Lost Core

The lost core manufacturing process closely resembles the sand-casting process that is used could be made out of aluminum could be made using the lost core process. The lost core process can even make some parts that would not be possible in aluminum.

The one piece seamless design also produces parts with excellent burst resistance. The major quality test in AIM's is the burst pressure test. The goal of the test is to simulate an engine backfire. The one piece design eliminates seams or joints which are a major source of these failures.

The main problem with the lost core process is cost. While it is less expensive than aluminum casting and machining it is still a long and costly process. With each part a disposable core is made. The material from this core is reclaimed, but you still have the cost to produce a core and remove the core.

Associated with the part cost is the capital required to produce parts with this process. In addition to the standard injection molding machine and tooling there are other significant pieces of equipment. The first step is to produce a core. This can be done with either a Die Casting Machine or Sand Casting Process. Both of these processes require tooling. The core manufacturing process requires an equivalent capital outlay to the injection molding. The major piece of capital is the core melting bath. This unit has precision temperature control and a conveyer or rack system to place the parts into the oil bath. The oil bath also has to have a reclaiming system for the metal used in the cores. The capital cost of this is again similar to that of an injection molding machine and tooling.

The Next Step:
Shortly after the first lost core AIM became commercialized work began on a simpler method to produce AIM's. This is the Welded AIM. A welded AIM is molded in two or more pieces or shells. These shells are designed to function in a standard injection molding tool. So all the features are in line of draw or mounted in standard slides. The shells are then welded together using a vibration welding technique.

Vibration welding is part of the family of friction welding. In vibration welding the joining surfaces of two parts are rubbed across each other. This friction causes the material at the weld join to melt. When this occurs the rubbing is stopped and the parts are clamped together. Upon cooling the parts are permanently welded together.

in the manufacture of metals. Nylon 66 with 30% to 35% glass fiber is the material of choice for manufacturing AIMs using this method.

First, a core is made of a metal alloy that has a low melting point. Next, the core is placed in the injection molding tool. Then, the AIM, made of nylon 66, is molded around the core. Finally, the polyamide 66 AIM and metal core are placed in a hot oil bath.

The oil baths usually run at temperatures of 220°C to 240°C. Because the metal alloy cores have a melt temperature of about 200°C, they melt in the oil bath. The one-piece, seamless polyamide AIMs remain.

Nylon 66 is the ideal material for lost core manufacturing operations. With its high melt point of 260°C, polyamide 66 easily withstands the high temperatures of the oil bath. In contrast, nylon 6 has a melt temperature of 225°C and could not survive the hot oil bath.

Advantages of Lost Core

The lost core process gives AIMs designers exceptional design freedom. Nylon 66 is ideal for any AIM that can be made of aluminum – and for some parts that *can't* be made of aluminum.

Seams or joints in AIMs are a major source of failure when engines backfire. The burst pressure test, which simulates an engine backfire, is the most important quality test for AIMs. Because the lost core method produces one-piece, seamless nylon parts, the resulting nylon 66 AIMs have excellent burst resistance.

Disadvantages of Lost Core

The main disadvantage of the lost core method of manufacturing nylon 66 AIMs is cost. While lost core manufacturing is less expensive than aluminum casting and machining, it is still a long and costly process.

Compared to Lost Core AIM's the major benefit of Welded AIM's is cost. The capital cost about half of that in Lost Core. There is the injection molding machine and the tooling that is similar. The other cost is the vibration welder and it tooling. This is about half the cost of the injection molding process.

The cost per part of a Welded AIM's is significantly lower as well. The injection molding cycle is the major cost portion. The welding operation takes place during the next molding cycle. This adds little cost to the process. Also there are no lost operations like the Lost Core process.

The Welded AIM's do have there drawbacks. Because of the vibration welding process all of the weld joints must align in a single plane. This limits the design freedom that is available. Also each weld joint must have a weld flange that sticks out from the part about 5 to 10 mm. This allows the parts to be gripped properly for vibration and allows a surface for clamping. Given the tight confines underhood this space can be difficult to find.

There is a new variation of the Welded AIM using Laser Welding. The process is in its infancy. It uses the laser heat to melt the material. The weld flanges can be made smaller because the movement isn't needed. But the flange is still needed for clamping. The major concern with the process is that the parts must be in full intimate contact. If a warp were to cause the parts to separate there will be no weld formed in that area.

A New Direction:
The new direction in AIM's is adhesive bonding. This technology tries to expand upon the benefits of welded AIM's, while addressing some of the drawbacks. This is done with minimal negative impact.

The greatest advantage to this technology is the design flexibility. Where vibration welding requires the joint to be in one plane (figure 1), adhesive bonding only requires that parts can be assembled in line of draw. If the two parts can be mated together then it can be adhesive bonded.

A disposable core made of a metal alloy must be created for every nylon 66 AIM produced. Even though the material from this core is reclaimed from the hot oil bath, there is still the expense of producing the core, removing it from the nylon AIM and then recovering the melted metal from the hot oil bath.

The core-melting bath unit is equipped with precision temperature control and a conveyer or rack system that places the parts in the oil bath. The oil bath also has a reclaiming system for recovery of metal used in the cores.

The capital investment in lost core manufacturing equipment is four times greater than the capital cost to establish an injection molding system. Four major components are required for lost core production operations:

- Injection molding machine and tooling
- Either die-casting or sand-casting equipment and tooling
- Core-melting bath
- Metal reclaiming system for bath

Vibration Welding

Shortly after the lost core process of manufacturing polyamide 66 AIMs became commercialized, work began on a simpler method to produce nylon AIMs, a method that involves welding.

A welded nylon AIM is molded in two or more pieces or shells. These nylon shells are designed to function in a standard injection molding tool. This means that all the features must be in line of draw or mounted in standard slides.

The polyamide shells are then welded together, using a type of friction welding known as vibration welding. Vibration welding requires that all of the parting lines lie in a single plane. A flange around the perimeter of each weld joint is also required. This flange, which extends approximately 5 to 10 mm, allows the nylon shells to be gripped properly for vibration and provides a surface for clamping.

The clamp pushes the shells together while the weld joints are rubbed across each other.

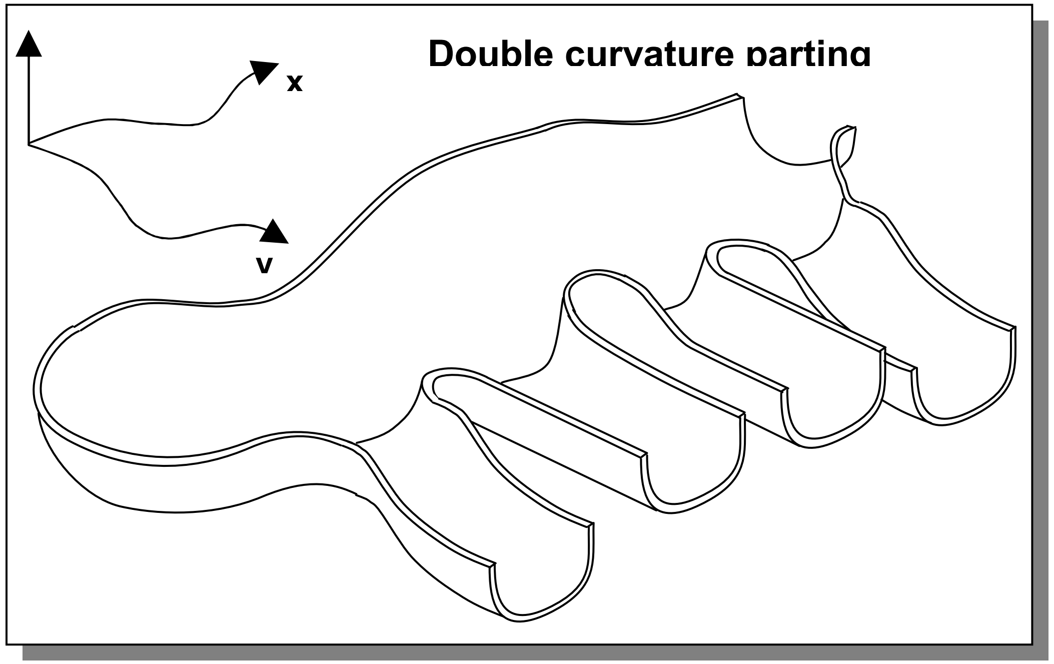

Figure 1

Adhesive bonding uses a tongue and groove joint that is only about 3mm wide. Vibration welding has a joint and flange that is about 8mm wide around its perimeter (figure 2). This results in adhesive bonding having better utilization of the packaging space.

The friction that is generated by the vibration melts the nylon material at the weld joint. If the shell is warped, as the shells are pushed together, the melted nylon material fills in minor gaps.

When the nylon material at the joint is sufficiently melted, the rubbing stops and the shells are clamped firmly together. The joined nylon shells cool to form a permanent weld and a finished polyamide AIM.

Laser Welding

A laser welding technology is currently being developed. Still in its infancy, this approach uses laser heat to melt the polyamide material at the joints. Flanges are needed for clamping, but they can be made smaller than with the vibration method of welding. The smaller flange provides better utilization of the packaging space.

The major concern with the laser welding process is this: gaps in the weld will occur unless the shells are in full intimate contact. Laser welding does not accommodate warped shells, as does vibration welding.

Advantages of Vibration Welding

Compared to the lost core process, a major benefit of vibration welding is capital cost. The cost to establish a welding operation is half the capital cost of a lost core process. The vibration welding manufacturing process requires:

- Injection molding machine and tooling
- Vibration welder and tooling

The cost per part of a welded AIM is significantly lower as well. The injection molding cycle accounts for the majority of the production expense. The comparatively inexpensive welding operation takes place during the next molding. Also, there are no lost operations, as there are in the lost core process.

Disadvantages of Vibration Welding

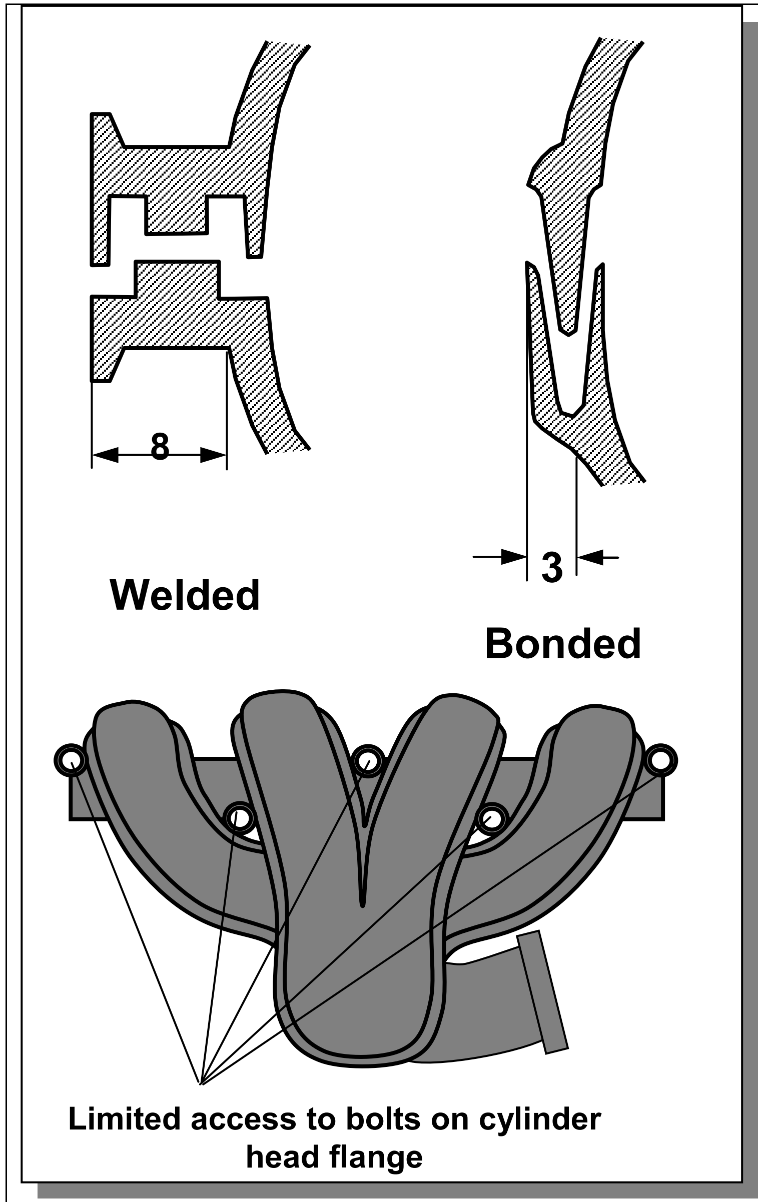

Figure 2

Welded AIMs do have their drawbacks. The vibration welding process requires that all of the weld joints align in a single plane. This limits designers' freedom.

Also, the flange occupies additional packaging space underhood, which may be difficult to find.

Adhesive Bonding

The latest polyamide AIM manufacturing process to emerge is adhesive bonding. This technology expands the benefits of welded nylon AIMs, while addressing some of the drawbacks of welding.

The process of making adhesive-bonded polyamide AIMs is simple. First, the shells are molded. Then a robot applies the adhesive to the groove portion of the tongue-and-groove joint, which is approximately 3mm wide. Next, the shells are clamped together to initiate the adhesive cure. Finally, the joined shells are placed in an oven at 120°C for 30 minutes to achieve a full cure and the final polyamide AIM.

The clamping process in adhesive bonding can be done with traditional clamping fixtures, although the most economical clamping method involves snap fits added to the sides of the shells (Figure 1).

The adhesive bond joint does not require a clamping fixture that grabs the full perimeter of the part. The runner of the AIM can even share a common wall (figure 3). This can improve the packaging space or allow for increased runner size to increase performance.

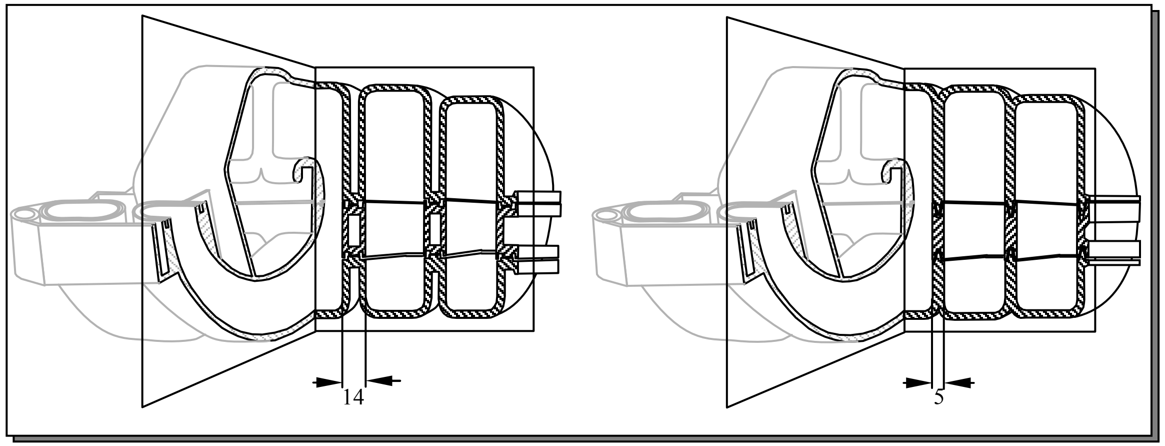

Figure 3

The tongue and groove joint used in adhesive bonding has a greater surface area. This improves the sealing and makes the joint stronger. Most of the vibration weld joint is used as a flash trap to make the part look better (figure 4). The sealing area of this joint is only about one quarter of that of the adhesive bonded joint.

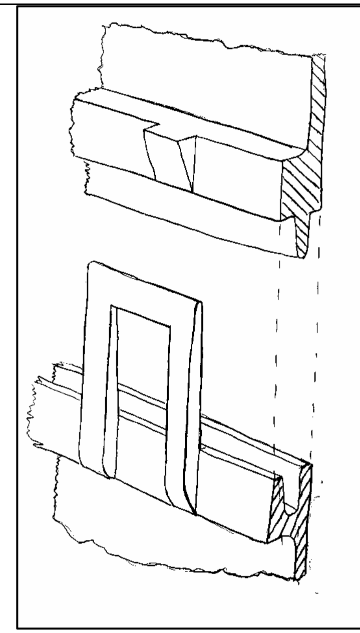

Figure 1

Another clamping method is staking and screwing (Figure 2).

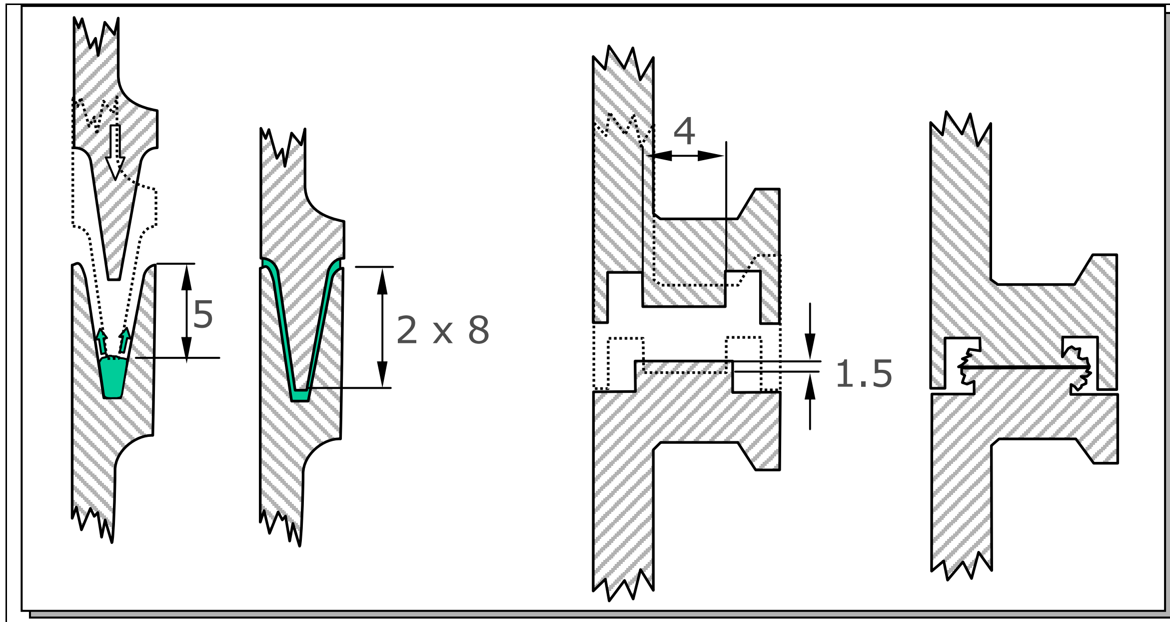

Figure 4

Adhesive bonding can allow for variable strength in the AIM. The strength of the joint can be changed by adjusting the depth of the tongue and groove joint. The diagram below (figure 5) shows the plenum having a larger joint than the runners. This is done to give the plenum more strength in the backfire burst test.

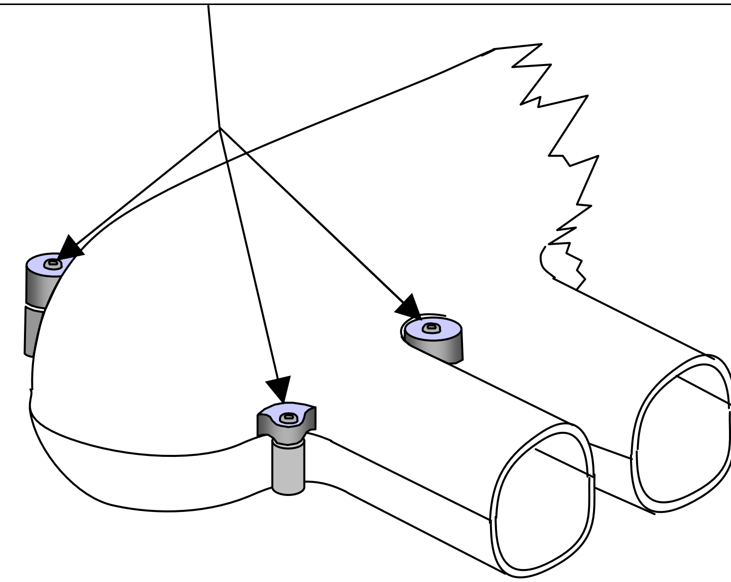

Figure 2

Minor warpage in the shells is usually not a major concern with adhesive bonding since the tongue-and-groove joint is self-aligning. However, if warpage is an issue, alignment pins can be added to the design (Figure 3). The alignment pins can also be designed as snap fits to provide clamping.

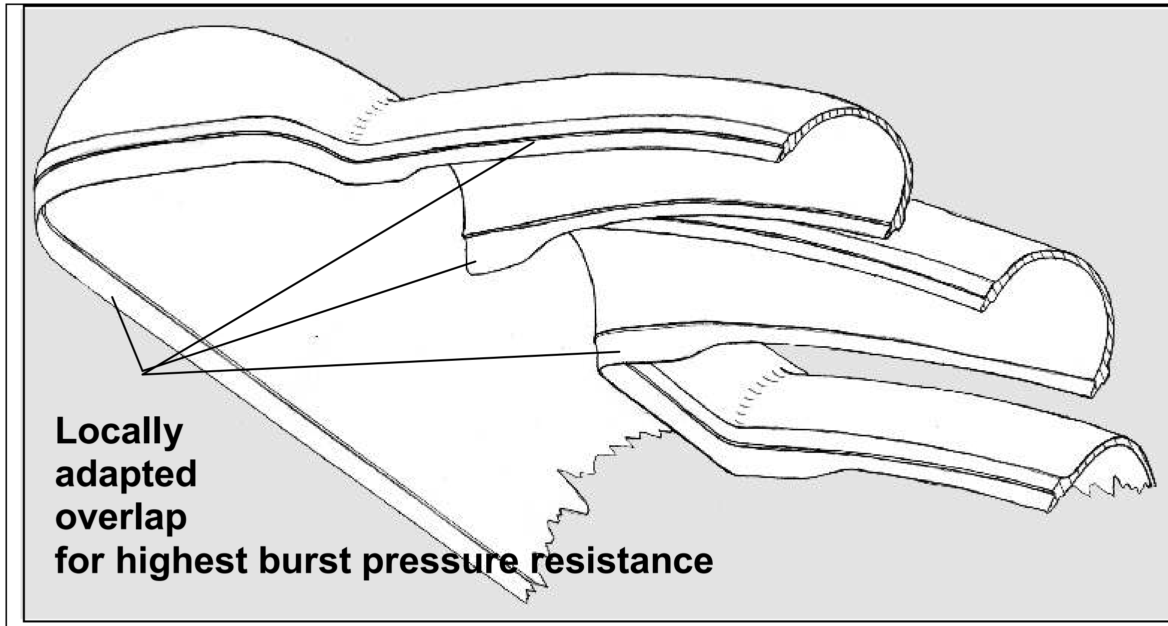

Figure 5

As with any different process technology there are some drawbacks compared to the other methods to produce AIM's. Compared with welded AIM's the adhesive bonded AIM's require the use of an added adhesive. This adhesive is a cost added to the production of the parts.

With both the lost core and welded technologies the parts can be tested almost immediately after they are molded. The adhesive bonded parts require that the adhesive cure before testing. This curing takes about 100 minutes after the parts are bonded.

The process to produce an Adhesive Bonded AIM is very simple. First the parts are molded. Then a robot is used to apply the adhesive to the groove of the joint. Next the parts are clamped to initiate the adhesive cure. Finally the parts are placed in an oven at 120°C for 30 minutes to achieve a full cure.

The clamping process in adhesive bonding needs to be discussed further. This can be done with tradition clamping fixtures. These will produce good weld joints but they do add cost

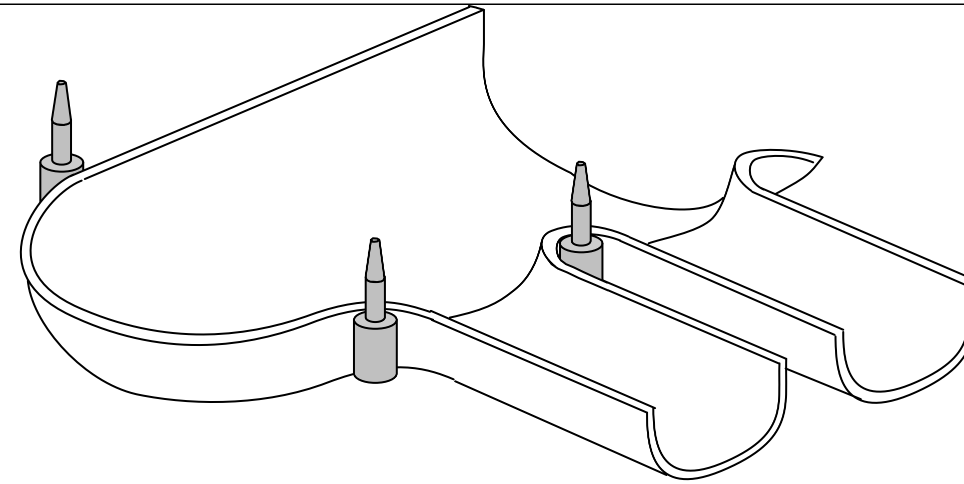

Figure 3

Advantages of Adhesive Bonding

The greatest advantage of the adhesive bonding process is design flexibility. While vibration welding requires that the joint be in one plane, adhesive bonding requires only that the nylon shells be assembled in line of draw (Figure 4). If the nylon shells can be mated together, then they can be bonded with an adhesive.

to the process. The most economical method is to design snap fits on to the side of the part (figure 6). Other clamping methods that can be designed in are staking and screwing (figure 7). Again these add process steps and costs to the product.

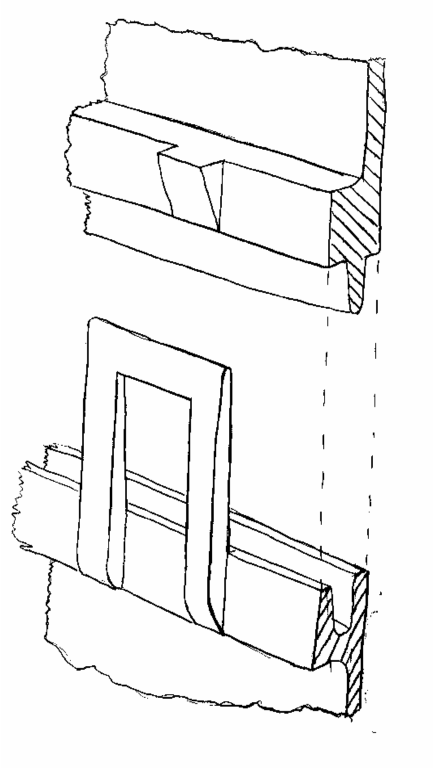

Figure 6

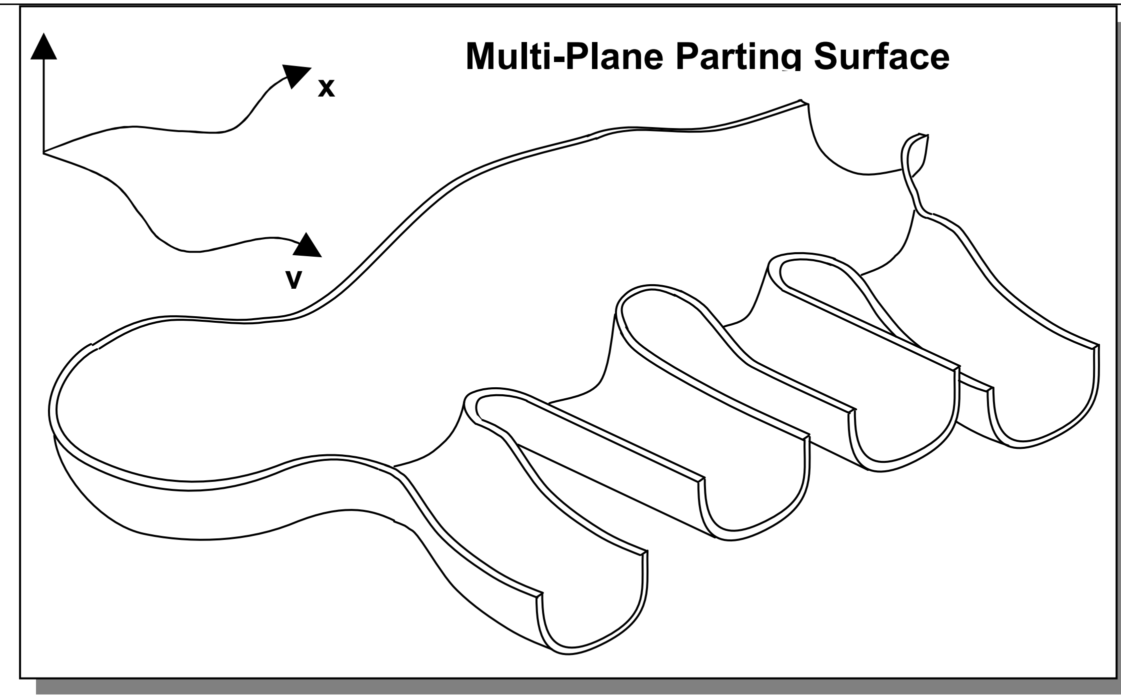

Figure 4

Adhesive bonding uses a tongue-and-groove joint approximately 3mm wide. Considering both the joint and the flange that vibration welding requires, a welded joint occupies approximately 8 mm around the perimeter of the finished polyamide AIM (Figure 5).

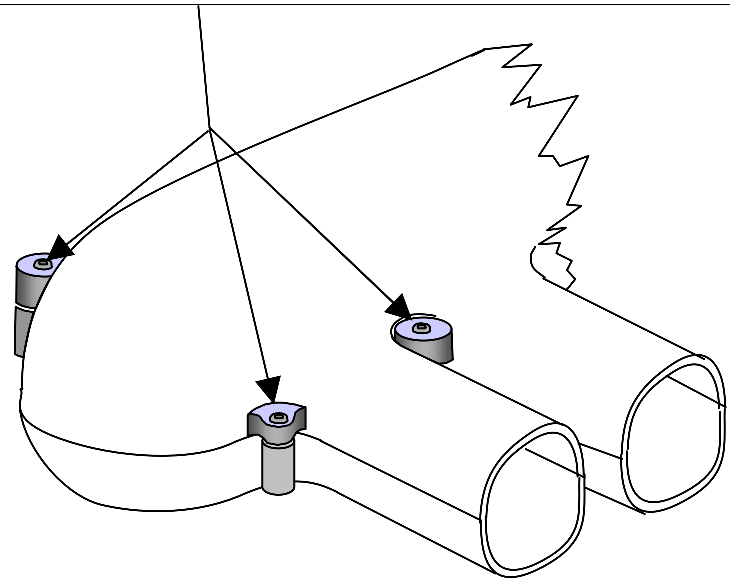

Figure 7

Minor warpage in the parts is not a major concern with adhesive bonding. The tongue and groove joint is self aligning. If needed alignment pins can be added to the design of the part if that is considered to be an issue (figure 8). The alignment pins can also be designed as snap fits to provide clamping.

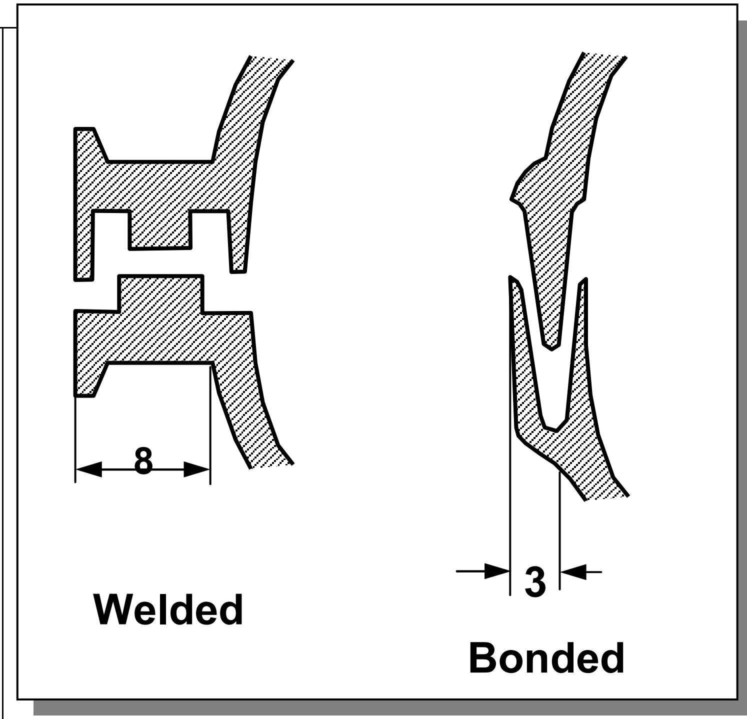

Figure 5

Since adhesive bonding does not require a flange, this method delivers better utilization of the packaging space than does vibration welding.

The tongue-and-groove joint used in adhesive bonding has a surface area four times greater than the welded joint: 16 mm compared with 4 mm (Figure 6). This improves sealing and makes the joint stronger. Most of the vibration weld joint is used as a flash trap, just to make the nylon part look better.

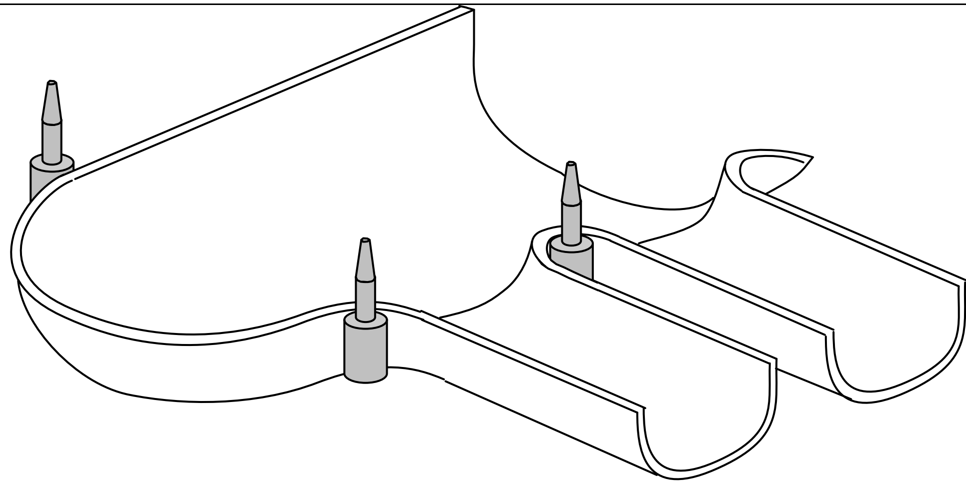

Figure 8

Any time there is a new technology such as adhesive bonding for AIM's, there are always questions about cost. The chart below is a comparison of the relative variable costs of each process (figure 9). Adhesive bonding has a variable cost slightly higher than vibration welding on a one-to-one comparison due to the addition of the adhesive. Adhesive bonding can help avoid the costly lost core process while providing similar design flexibility. Additional optimization opportunities exist with adhesive bonding to allow for a cost equal to vibration welding. Also note the capital and tooling investment for bonding is slightly lower than for vibration welding.

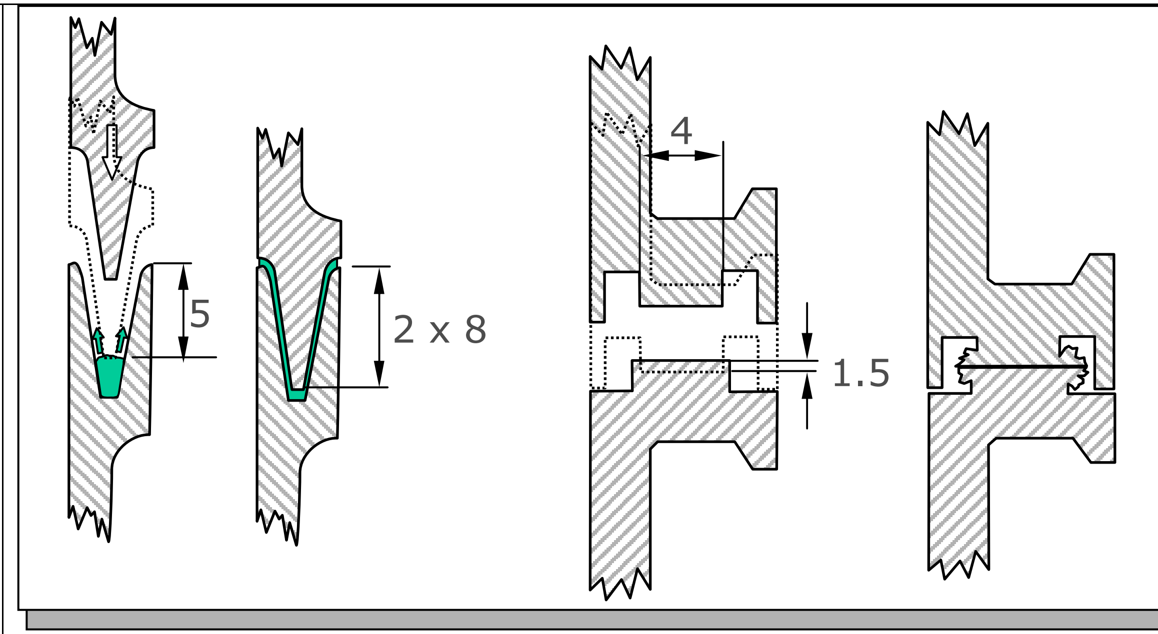

Figure 6

The runners of the nylon AIM can share a common wall (Figure 7), which further improves the packaging space. The increased runner size, which the shared common wall allows, further enhances the performance of the nylon AIM.

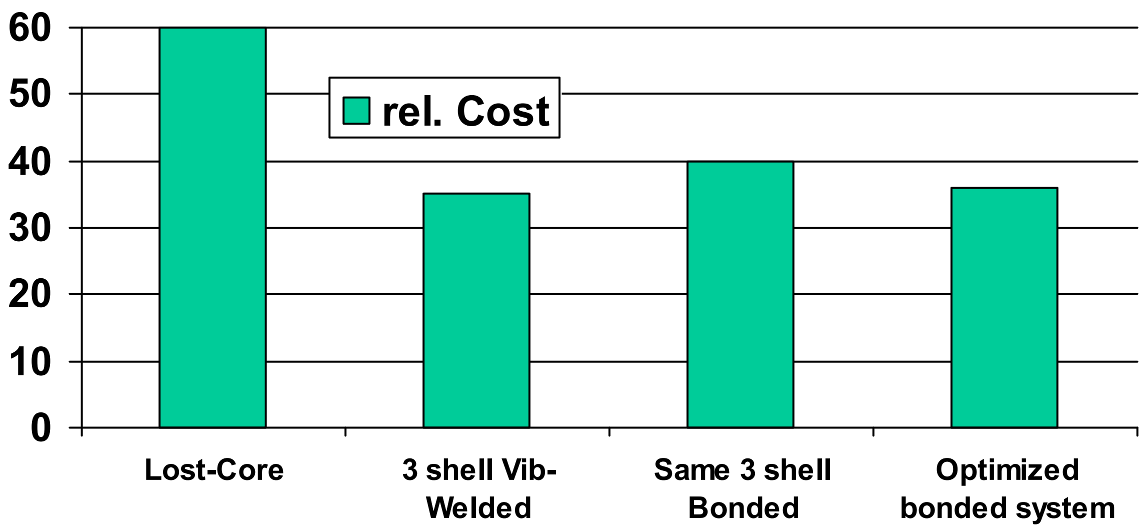

Figure 9

In the future the adhesive bonding process will allow for unique optimization. The potential exists to bond dissimilar materials. One example is that a polypropylene upper shell could be bonded to a nylon lower shell (figure 10). A polypropylene air filter housing could be integrated into a nylon AIM.

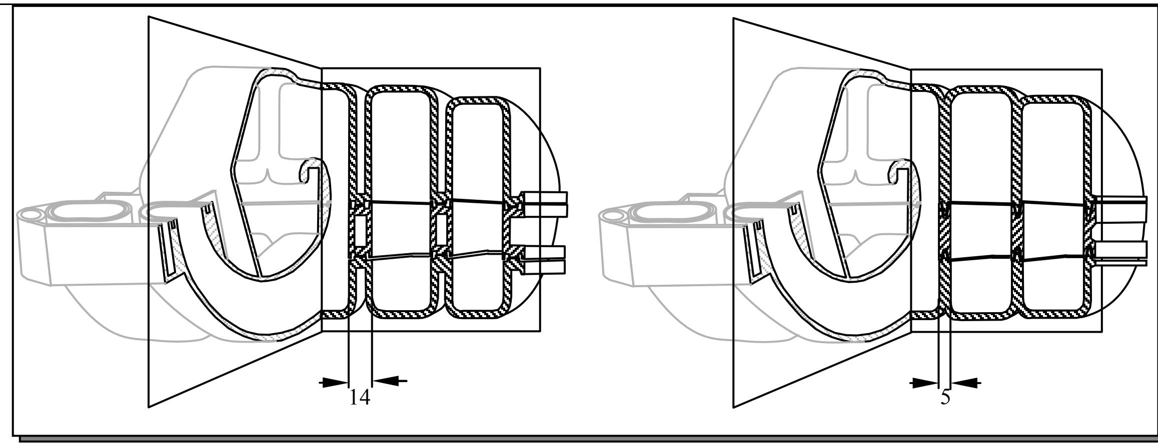

Figure 7

Adhesive bonding can also provide variable strength in the polyamide AIM, just by adapting the depth of the tongue-and-groove joint. For example, an AIM that has a plenum with a larger joint and relatively smaller joints on the runners will have greater burst pressure resistance (Figure 8).

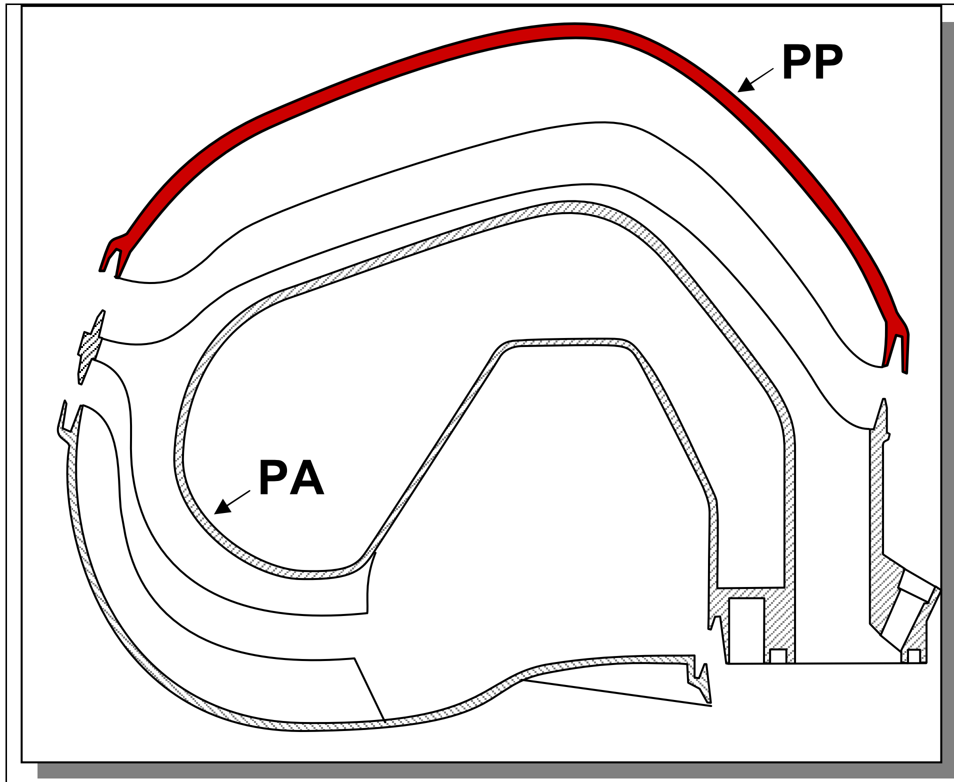

Figure 10

Summary:
Currently there exist three commercially accepted methods of producing plastic AIM's. The adhesive bonded AIM is not intended to replace the other production methods. Adhesive bonding is an alternative assembly process that can be utilized where existing methods have difficulty meeting all applications requirements. Cost savings are probable versus the lost core process. The process offers greater flexibility for optimized designs. The smaller joint profiles have higher strengths than vibration welding. Significant integration opportunities exist.

The development of the adhesive bonded AIM has been led by Dow Automotive. Dow Automotive has specifically developed the Betamate 2K Epoxy system for the AIM

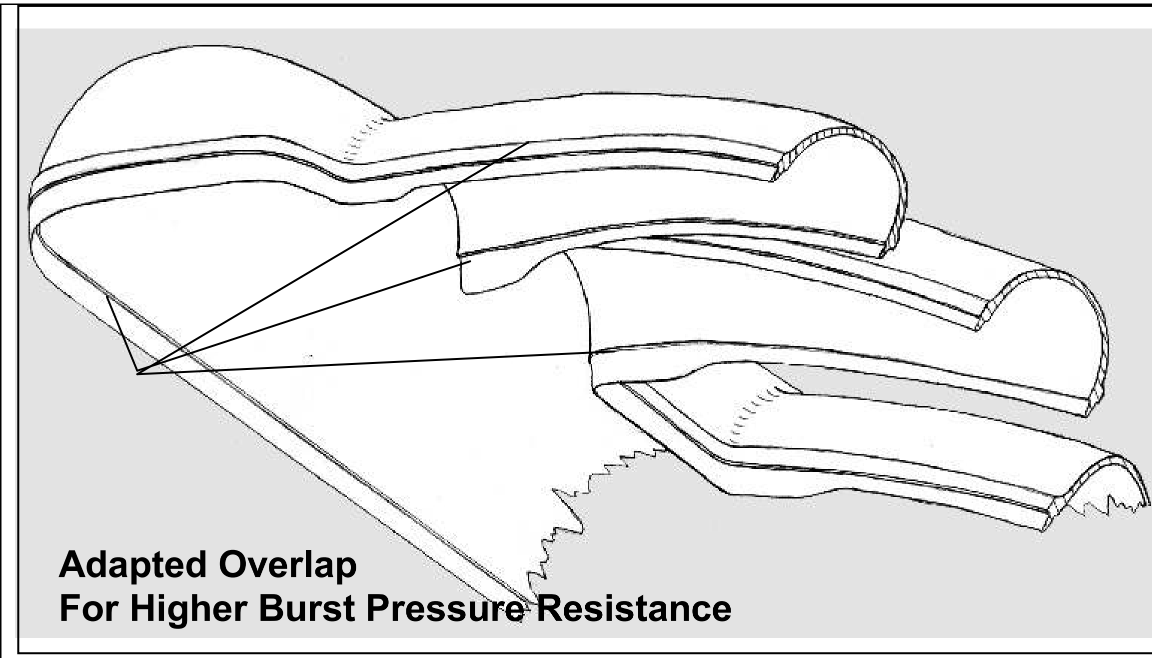

Figure 8

A final advantage of adhesive bonding involves the additional optimization opportunities that exist, e.g., smaller joints, smaller nylon AIMs, lower weight, more available packing space.

Disadvantages of Adhesive Bonding

When compared to the other methods of producing polyamide AIMs, adhesion bonding has a few drawbacks.

First of all, there is the adhesive itself, an additional material that is not required with vibration bonding. Applying the adhesive adds another step to the production process, thereby increasing per-product cost.

If the staking and screwing method of clamping is employed, it adds another step to the market. Solutia, Inc. has supported the development of this process. Specifically the Vydyne R535WH (Nylon 66, 35% Glass Fiber) has been formulated to work with this process as well as in vibration welding.

production process.

With both the lost core and vibration welding technologies, the finished nylon AIMs can be tested almost immediately after they are molded. The adhesive-bonded nylon parts must be cured before testing. This curing takes about 100 minutes after the shells are bonded.

Cost Comparison of Manufacturing Methods

The chart below compares the relative variable costs of each manufacturing process (Figure 9). The cost of the adhesive in adhesive bonding is an additional variable cost that is not required with vibration welding. Compared to the lost core technology, the cost of adhesive bonding is much lower, although the design flexibility is comparable. When designers take advantage of the optimization opportunities available with adhesive bonding, the cost of adhesive bonding then compares to the cost of vibration welding.

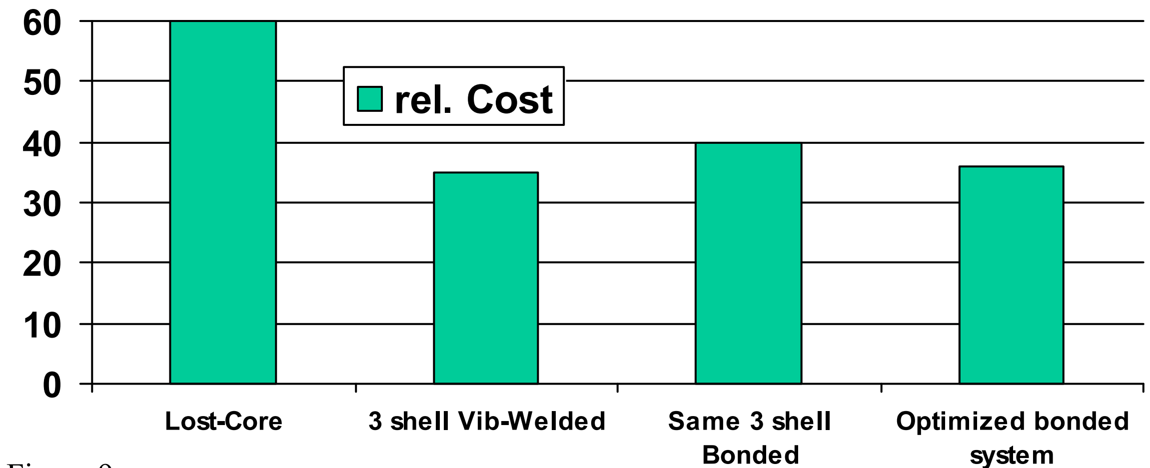

Figure 9

Though not shown on this chart, it is worth noting that the capital investment in tooling required for adhesive bonding is slightly lower than the capital investment required for vibration welding.

The Future of Adhesive Bonding

In the future, the adhesive bonding process will offer unique optimization and integration opportunities, including the bonding of dissimilar materials. For example, a polypropylene (PP) upper shell could be bonded to a polyamide (PA) lower shell (Figure 10) or a polypropylene air filter housing could be integrated into a polyamide AIM.

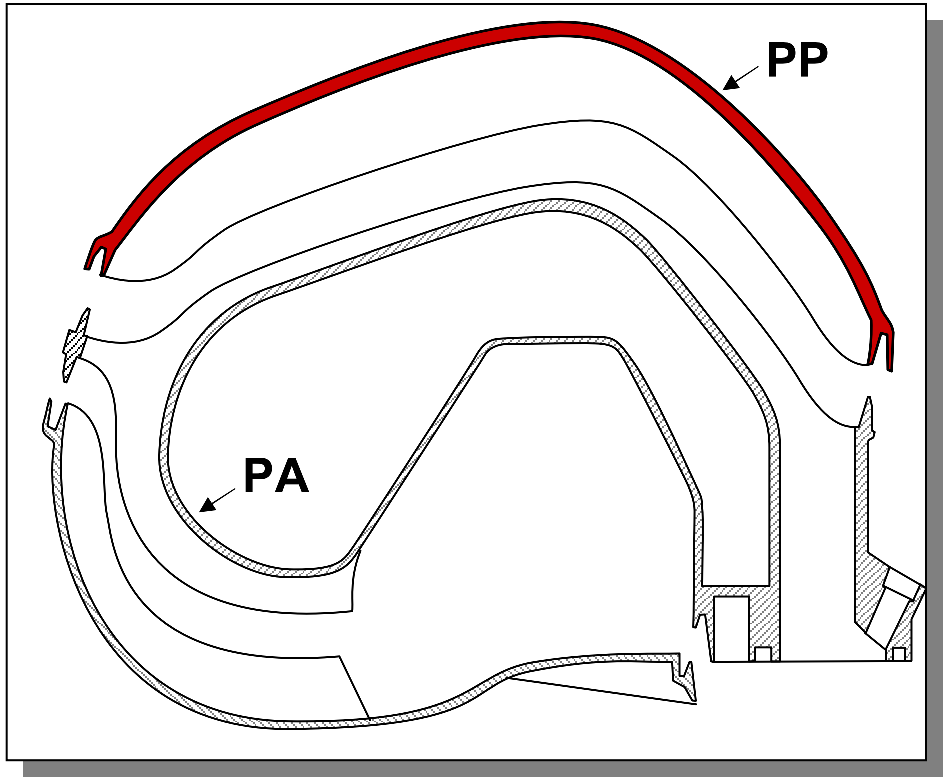

Figure 10

Conclusion

Currently there are three commercially accepted methods of producing polyamide AIMs: lost core, vibration welding and adhesive bonding. The adhesive-bonded AIM is not intended to replace the other production methods, but when lost core and vibration welding processes cannot meet all of the application requirements, adhesive bonding may be an effective alternative.

The advantages of adhesive bonding over the vibration welding process include smaller joint profiles, improved packaging space utilization, greater part strength and variable part strength. Compared to the lost core process, adhesive bonding typically offers cost savings. The adhesive bonding process also offers greater flexibility for optimized designs and significant integration opportunities.

* * * * * *

The development of the adhesive-bonded AIM has been led by Dow Automotive. Dow Automotive has developed the Betamate 2K Epoxy system specifically for the AIM market. Solutia, Inc. has developed Vydyne R535WH (nylon 66, 35% glass fiber), specifically for optimized performance in the adhesive bonding and vibration welding processes.