Abstract

New production technologies are increasing the performance of air intake manifolds (AIMs), while at the same time reducing both capital and production costs. This paper will help you sort through the various polyamide 66 AIM production processes and discuss the comparative advantages and disadvantages of each.

Introduction

Eighty percent of all air intake manifolds in production today are made of polyamide resin. Since the 1970s and 1980s, when polyamide 66 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 to manufacture metals. Nylon 66 with 30 percent to 35 percent 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 bath usually runs at temperatures of 220°C to 240°C. Because the metal alloy core has a melt temperature of about 200°C, they melt in the oil bath. The one-piece, seamless polyamide 66 AIM remains.

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.
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. 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 66 AIM.

Adhesive Bonding

The latest polyamide 66 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 66 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 3 mm 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 66 AIM.

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

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.

Adhesives vs. Welding

While the advantages of adhesive bonding are its ease of use and cost savings, welding provides a stronger bond.

Disadvantages of Adhesive Bonding

Although adhesive bonding is a faster process, it can be challenging to ensure a consistent bond, especially in high-temperature environments.

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.

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 recovering the melted metal from the hot oil bath.

The core-melting bath unit is equipped with precision temperature control and a conveyor 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...
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).

Another clamping method is staking and screwing (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.

Adhesive bonding uses a tongue-and-groove joint approximately 3 mm 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 66 AIM (Figure 5).

Adhesive bonding can also provide variable strength in the polyamide 66 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).

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.

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.

A final advantage of adhesive bonding involves the additional optimization opportunities that exist — e.g., smaller joints, smaller nylonAIMs, lower weight, more available packing space.
Disadvantages of Adhesive Bonding

When compared to the other methods of producing polyamide 66 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, this adds yet another step to the 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.

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 66 AIM.

Conclusion

Currently there are three commercially accepted methods of producing polyamide 66 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 percent glass fiber), specifically for optimized performance in the adhesive bonding and vibration welding processes.
Polyamide 66 Air Intake Manifolds: Compare Your Manufacturing Options

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