Plastic Exhaust System using 3D Blow Molding

Submitted to
SPE Blow Molding Division

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Introduction:

Plastics have become viable alternatives to traditional materials in many applications. Many automotive parts are manufactured in plastics because of advantages over traditional materials. Automotive industry desires lightweight and high strength components. The complexities of shape and better environmental properties have led to penetration of plastics in the interiors of the car. High performance plastics have also made their mark in ‘under the hood components’. Easy and quick manufacturing and simple assembly have made plastics a natural choice for various components. In this paper we propose to replace parts of the exhaust assembly with plastics. To achieve accurate dimensions and high performance, blow-molding process can be employed. Using plastic exhaust can eliminate multiple parts thus reducing complexity and provide a simpler operation for the assembly plant. This part integration makes assembly easier, lowers weight and cost and improves performance.

Blow Molding:

The 3D approach is ideal for molding long, convoluted automotive ducts and pipes. It is very difficult to form the extruded pipes in required shape. 3D blow molding achieves the high level of accuracy in one step. Also, the advantages of the 3D blow molded part versus a conventional extrusion blow molded version are two - minimal flash generation and absence of vulnerable parting lines. A new suction blow molding technique can produce 3D parts made of high-temperature materials—i.e., melt temperatures from 250 to 360 C (480 to 680 F). In suction blow (a form of extrusion blow) the parison is conveyed directly from the parison die head into the closed blow
mold and is drawn through the mold by vacuum. Once the bottom end of the parison emerges from the blow mold, the parison is pinched off by shutters and then inflated, enabling complex three-dimensional shapes to be produced. The machine has an extruder with special screws designed for gentle plasticating and homogenizing of high-temperature materials. Also, the mold is preheated to prevent premature cooling of the parison as it is sucked through the mold.

The design achieved by Blow molding is very simple and eliminates various steps of bending; welding etc. The current manufacturing process also improves ergonomics for assembly operators. Blow molding will lead to fast manufacturing and higher mechanical properties. Scrap is very low in this technique and thus, it will achieve cost reduction. Better properties are obtained by the use of 3D blow molding technique. 3D blow molding has various advantages over conventional processes, which include, higher molding quality due to absence of welding seams, no reduction of strength resulting from material accumulation or notches at welding seams, more uniform wall thickness distribution, low flash waste and consequently lower amount of regrind, lower operating costs due to the reduced amount of material to be melted and cooled and optimized wall thickness to compensate wall thickness variations in bends and in case of prior mold contact the radial wall thickness control is possible.

Material Selection:

Selection of material for any part is very crucial in the design considerations. While evaluating resins for this application, we must balance a variety of needs such as impact strength, rigidity, chemical compatibility, melt strength and processability. The
high temperatures in the exhaust system have rendered us to look for high performance plastics. Gases, which leave the catalytic converter, are at $200 \degree C^{[2]}$. The durability of plastics at the service temperature is very important. We select glass filled Polyphenylenesulfide (G-PPS) based on its thermal and mechanical properties. The low cost and good processing characteristics make G-PPS an attractive choice for manufacturing blow molded article. Similarly, the high stiffness, high heat resistance and outstanding stress crack resistance ensure the performance in the aggressive chemical environment and large range of working temperatures. ‘Under the car’ parts have to sustain impacts from below and this grade has good impact strength also. Water absorption is very low. Following is the table of properties for commercial grade G-PPS$^{[3]}$.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Izod impact strength</td>
<td>75-80 J/m</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>7-12 GPa</td>
</tr>
<tr>
<td>Heat Deflection Temperature</td>
<td>260 $\degree$C</td>
</tr>
<tr>
<td>Upper Working Temperature</td>
<td>230 $\degree$C</td>
</tr>
<tr>
<td>Resistance to acids and alkalies</td>
<td>Good</td>
</tr>
<tr>
<td>Resistance to hydrocarbons and halogens</td>
<td>Good</td>
</tr>
</tbody>
</table>
Design details:

Current design is based on the traditional exhaust system design. Selection of material is very critical and has been discussed in the previous section. The exhaust system will consist of following parts:

- A-pipe
- Muffler housing
- Honeycomb structures
- B-pipe

A-pipe, muffler housing and B-pipe are individually blow molded and then easily fitted into each other and onto the catalytic converter. 3D blow molding is employed for the production of pipes. Conventional blow molding process can be used for the muffler housing in the current form. For more complicated muffler designs 3D blow molding process can be used efficiently. Programmed parison extrusion can achieve the desired thickness in various sections \[^4\]. Honeycomb structures are required for noise reduction and are commercially available.

The thickness of the honeycomb pipes and the A-Pipe is 5mm (0.1969”). The thickness of the B-pipe is 5mm in the thin part and 10mm in the thick part. The thickness of the muffler housing is 10 mm. The muffler wall dimensions can be chosen appropriately to fulfill the mechanical requirements for the part (impact strength, bending, stiffness). Important parameter here is the blow–up ratio - the ratio of the mold cavity diameter to the diameter of the parison or hollow form to be blown up. A blow-up ratio of 3:1 is recommended for best wall thickness uniformity. The dimensions of the extrusion die should be chosen accordingly.
There are three common methods for joining – heat fusion, electro-fusion and mechanical fittings. All three of these joining methods provide leak-free plastic piping systems in the gas distribution industry. A-pipe can be fitted onto the catalytic converter using mechanical fasteners developed for plastics. The A-pipe and B-pipe can be joined to the muffler housing by the method of fusion. The honeycomb structures can be mounted on the A-pipe and B-pipe using adhesives. The assembled components are then inserted into the muffler housing and fusion bonded to the end walls. The pipes can be supported under the car using hangers. The muffler housing is supported on the two pipes.

Alternatively, elimination of honeycomb structures can be obtained through innovative design of the muffler housing, which can lead to a single component system. The geometry and gap variation inside the housing can lead to sound reduction without the honeycomb structures. A simple obstructive geometry that causes reduction in exhaust gases velocity and destructive interference will reduce noise. In depth analysis of wave propagation can lead to custom exhaust systems based on various blow molded designs, which can have various sound levels. However, sound reduction design is beyond the scope of this paper.

Picture illustrations are attached to show the details.
Figure 1: Outer view of the designed assembly

Figure 2: Sectional view showing the placement of the parts
Figure 3: Dimensions of various parts
References:


2. “New technology to vary the thickness of the parison in circumferential direction during the blow molding process” Gross H. G., Kunststoff H. G.
