Increasing diaphragm hydroforming productivity with rapid prototyping

The role of fused deposition modeling

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Sheet metal forming using liquid media, or hydroforming, is well-known and used for producing parts in low production volumes. Hydroforming involves pressing the sheet with liquid pressure against a die or a punch.

A variation of hydroforming uses a diaphragm that separates the pressurized liquid from the sheet metal so that the possibility of leakage is eliminated (see Figure 1). With this variation, called flexforming or diaphragm hydroforming, the sheet metal is pressed against half a rigid die and half a flexible rubber diaphragm, backed up by hydraulic pressure. The blank takes the shape of the rigid tool. Because only half a die set is used, with the diaphragm acting as a flexible die or punch half, tool costs are reduced.

The diaphragm hydroforming process is used in the automotive industry for producing prototype and development parts. The aerospace industry uses it for making production airframe and engine components. In small production volumes, the relatively low cycle time is justified by the reduced tool costs.

Diaphragm hydroforming can be used to form aluminum alloys, mild steel, and stainless steel of various sheet thicknesses. The pressure needed to form a given part increases with increasing sheet thickness (0.0039 inch to 0.197 in.) [0.1 millimeter to 5 mm] and tensile strength of the sheet material, as well as with decreasing corner and fillet radii on the part.

Another variation of diaphragm hydroforming is illustrated in Figure 2. In this process, the blank is placed on the lower surface and pressed against the tool. The lower punch moves upward against the pressure-backed diaphragm and forms the part. This design can be modified and programmed to function in diaphragm-only mode or in diaphragm-and-punch mode.

**Fused Deposition Modeling**

The productivity of diaphragm hydroforming for manufacturing aerospace sheet metal parts is increased considerably through the development of rapid tool and die manufacturing techniques. One such tech-
nique uses the rapid prototyping method called fused deposition modeling (FDM) (see Figure 3). A spool of thin plastic filament feeds material to a liquefier head that melts the plastic by a resistance heater. The molten plastic is extruded to form a thin layer that solidifies to form a laminate. The path of the extrusion is determined by the position of the FDM head, controlled by CNC. The next layer is deposited on the previous laminate, and they are fused together. If needed, a support structure also can be built up for parts that have undercuts and need backup support.

Newly developed FDM machines can handle polymers that, when solidified, maintain pressures of 10,000 pounds per square inch (PSI) or more. Thus, a die block can be rapidly manufactured with this method for use in diaphragm hydroforming of various aluminum parts.

**Aluminum Part Production**

Figure 4 illustrates how the rapid tool manufacturing technique was used at The Ohio State University’s Center for Precision Forming (CPF) in combination with diaphragm hydroforming to produce an example part from aluminum 2024-O blanks (0.063 in. and 0.0900 in. thick). The top and bottom form blocks were manufactured using FDM technology. The blank, cut to the desired geometry, was placed between the form blocks and located on the lower surface of the hydroforming machine. A pressure of 10,000 PSI was built up, without activating the lower punch.

The preliminary tests indicated that rapid tool manufacturing, combined with diaphragm hydroforming, has significant potential for forming aluminum-alloy sheet metal parts in low-volume production quantities for the aerospace industry, as well as for repair and prototyping applications. However, development work is needed to determine the pressure the tool material can withstand, tool life, and the design parameters that can be achieved.

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**Notes**

2. Ibid.