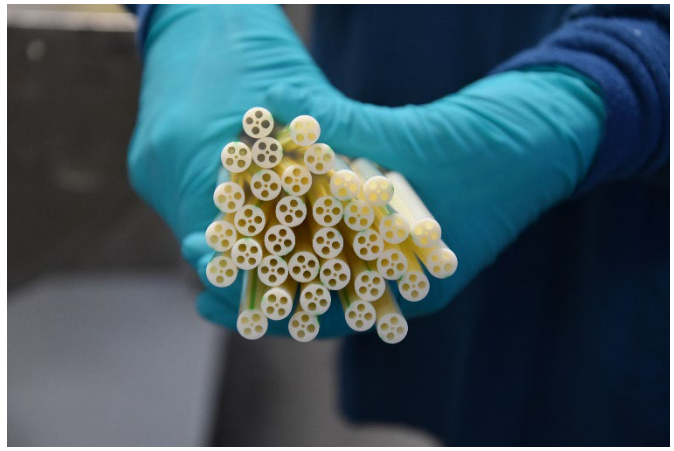
Tight-Tolerance Extrusion Engineering for a Multi-Lumen Blood Separation Device

Introduction

While Teel specializes in custom extrusion, Teel's team was put to the test creating multiple processing elements for a new blood separation product. The product, a multi-lumen tube, is installed into a blood separation device.

Teel was asked to develop a tube made of a new, higher-grade material to replace the customer's flex PVC tubes, which were failing due to abrasion and stress.



Multi-Lumen Blood Separation Tubing

Designing the Process

The first challenge was developing an extrusion pin design that would form the new, highly viscous material to the product's tight-tolerance, multi-lumen design.

The final product includes four larger outer lumens with one smaller lumen at the center of the tube. The four outer lumens needed to be within 0.003" from the lumens on either side. Other attributes (in all, approximately 24), including roundness and wall thickness, also needed to be controlled for, and the interdependence of the attributes meant that an adjustment to one would affect the others. While this balance would be difficult enough to achieve in itself, the viscosity of the elastomer material made it especially challenging to maintain the tolerance.

To produce the part geometry, Teel designed an intricate pin and die geometry create just enough draw to move the plastic through the die while avoiding the use of forced air and excessive stretching. This is counter to standard practice, where more viscous material is extruded with a higher draw. If Teel would have used a more standard drawdown ratio, the process would have required much more manual adjustment. Teel instead used water to prevent all contact between the plastic and any solid element of cooling tanks down the line to help overcome the viscosity of the plastic.

Second, instead of designing a circular pin matching the circular shape of the tubing, the pin is a modified polygon with reverse engineered hole shapes within it to create the five lumens at their proper dimensions. The design takes into account the speed at which the plastic moves into the pin and then swells (or bulges) out as it exits. In this way, the geometry of the pin allows the plastic to form into circular tubing as it swells while exiting the pin rather than forming the tubing into a more exact shape within the die itself.

To keep the extrusion process contactless, the plastic exits the die immediately into a first bath of water before it reaches a vacuum tank, which typically appears first on other extrusion lines. This further impacted the pin design, and the lumens had to be designed to swell out of the pin to accommodate.

While complicating the work of the engineer, this design makes extrusion line setup and production simpler for the operators, helping to prevent problems on the line.

Fabricating the Pin to Precise Dimensions

While the pin design created an elegant solution for processing the tubing, the next challenge was developing an intricate fabrication process to produce the stainless steel pins to their precise dimensions with the help of Teel's Tooling department.

The primary machining process is performed by Teel's Y-axis lathe. To produce the pins, the lathe machines a precut piece of steel through multiple operations.

First, the sloping angle of the pin body is machined to size by spinning the piece of steel against a milling drill. Holes are then drilled into the thinner end of the pin, for what will become the four larger outer lumens.

Afterward, three separate machining and measurement operations are performed to bring the lumens to their precise dimensions. The first is a milling operation to initially rough out the shape of the lumens. The lumens are then measured and machined again to a more precise size. The last operation is a "dry run" of the lathe over the lumens, meaning the typical petroleum-based coolant added to reduce the temperature of the tooling and remove metal chips is not used. Since this last pass typically involves shaving just 0.0005" of metal from the lumens, the shrinking effect of the coolant on the tooling and part would lead to an inaccurate cut. For reference, 0.004" is the width of a typical piece of paper. This last machining pass removes a layer of metal roughly one-tenth that width.

The center lumen is then fabricated on a separate grinding machine, where a small piece is drilled and then pressed onto the pin in the center of the four larger lumens.

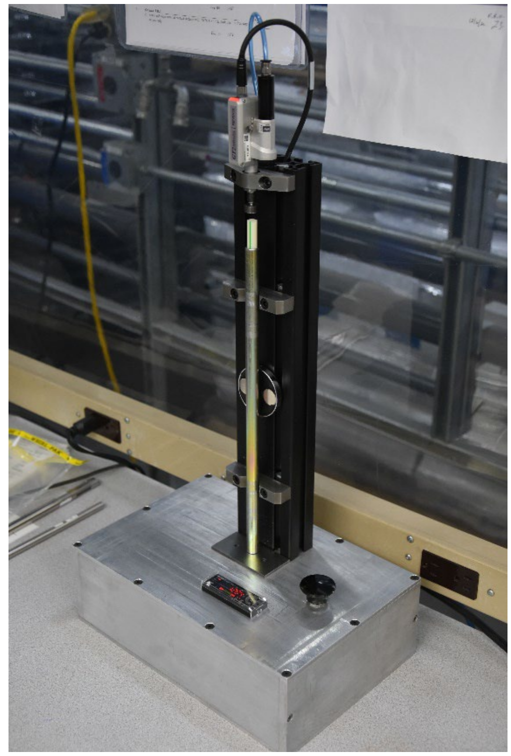
After the pin is complete, it is measured with a Nikon vision system in Teel's analytical lab capable of extreme magnification, revealing the machining marks in detail on a piece that looks and feels smooth to human senses.

Creating a Custom Measurement Device

The uniqueness of the part also made conventional quality control challenging, requiring further customization from Teel's engineering team. Because of its flexibility, the softer durometer part could not be measured accurately with a typical length gauge, so Teel designed and assembled its own measurement device specifically for the tube.

The custom device needed to keep the flexible part straight and reduce the pressure exerted on its two ends during measurement. Maintaining straightness was accomplished by housing the part inside a straight steel tube. The linear displacement sensor that contacts the part to perform a measurement is customized to exert minimal pressure to ensure accuracy and prevent bending.

To operate the device, the operator places the part vertically inside the steel tube. By operating a pneumatic switch, the linear displacement sensor actuates and contacts one end of the part, while the other end of the part is located against a datum surface. The measured length value is then displayed on a digital readout for the operators to record.



Teel's Custom Length Measurement Device

Conclusion

This product is an example of the numerous elements that need to be considered to develop a tight-tolerance medical tubing product. The geometry and characteristics of the material required not only a custom extrusion design, but also custom elements upstream and downstream of the actual extrusion process.

This product's successful development further exemplifies the value of Teel's engineering, analytical lab, and machining resources for those seeking customized solutions for challenging products. Teel specializes in closely partnering with customers to solve problems rather than merely offering conventional processing capabilities.