Blog - MEMS New Product Development, Importance of First Prototype

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In the second article of the MEMS new product development blog, the importance of the first prototype will be discussed. Theoretical work is valuable and a necessary step in this process but nothing shows proof of principle and sells a design like a working prototype. Its something people can touch, observe and investigate while distracting them from doubt associated with change. Building multiple prototypes in this first phase is equally important to begin validation early and show repeatability or provide evidence to change design and process directions.

The first prototypes should include both non functional and function samples. The non functional samples are used to test one or more characteristics such as burst strength of a pressure sensor element. Fully functional samples can be used to test multiple performance interactions. An interaction is likely to include how the packaging of a MEMS device influences its accuracy or how exposure to environmental conditions effect sensor performance over life. Lets look at a few examples of how prototypes can influence proper decision making and expedite new product development.

When working with an OEM on the development of a MEMS sensor, the team hit a road block with the customer pursuing one design direction (for very specific reasons) and the sensor team trying to make a change to improve sensor performance in fluid drainage. The sensor package had two long, narrow ports of specific diameter and the customer was resistant to change because of envelope size constraints and the need to retrofit legacy products in the field. However, the diameter of the ports was the most important factor in improving drainage. Engineers on both sides threw around theories for months with no common ground achieved before a prototype was made. Then a prototype was built with several different size ports and a drainage study was completed. A video was made showing visual evidence of the test results. It turned out that making a 2 mm increase in port diameter resulted in full drainage with gravity where the previous design held fluid until it was vigorously shook. When the customer saw the results of the prototype testing in the video, a solution to open port diameter was reached in just a days including a method to retrofit existing products in production.

For another application, the engineering team needed to develop a method to prevent rotation of a MEMS sensor package. The customer requested that rotation be eliminated with a key feature added at the end of a threaded port. One method to achieve this is through broaching. This method involves cutting a circular blind hole, using a secondary tool to cut the material to a slightly different shape such a hexagon and then removing the remaining chip with a post drill operation. When the idea was first introduced, most experts stated it was crazy to attempt such a feature in hardened stainless steel and no quoted the business. However, the team built a prototype to test the idea. Our first prototype successfully broached 3 holes and then the tool failed due to a large chip in the tool's tip. The team examined the failure and learned that the chip in the tool resulted from a sharp cutting edge. The material was also suboptimal for this broaching process but it was obtained quickly. Learning from these mistakes the team choose a more robust material and slightly dulled the cutting edge. These changes improved tool life from 3 to 92 broaches. This was a significant improvement but not to the point of a robust manufacturing process. Again learning from the prototype the team saw evidence heat was playing a role in the failure. This led the team to change to a more robust lubrication (something similar to the consistency of honey). This single, additional change improved tool life from 92 to over 1100 broaches and it was learned that increased tool life could be obtained with periodic sharpening and dulling the edge slightly. With further development, over 12,000 broaches were obtained in a single sharpening with tool life lasting over 96,000 broaches. Hence a prototype quickly showed proof of concept but also led to process and tool design changes that provided a successful solution.

The last example is of a fully functional, prototype MEMS pressure sensor. Prior to building a prototype, analytical tools such as finite element analysis were used to predict interactions between the packaging and sense element when large external loads were applied to package extremities. These models are highly complex and often misuse of the tool by non experienced users results in team skepticism of the results. Colleagues may refer to work of this nature as "pretty pictures" but not very meaningful or doubtful at best. However, when performed properly with attention to meshing, material properties, boundary conditions, applied loads and solvers accurate results can be obtained. This allows for multiple design iterations analytically prior to the first prototype to ensure the sensor has the highest probability of achieving the desired performance. After finding a design solution where the packaging had less than 0.1% influence on the MEMS sense element performance, prototypes were built to validate both the optimized (slightly higher cost, better predicted performance) and a non optimized design (lower cost, lower predicted performance). Upon validation of both prototypes the team found over 90% correlation between experimental and theoretical results. In addition, the first prototype (although having some flaws) was very functional and performed well enough to be used in a customer validation station. With high correlation between theory and experimentation, the once questionable results were validated as trustworthy and further FEA could be performed for design optimization.

In each of the case studies reviewed above, it was seen that early prototypes led to a wealth of information for the engineering team and proof of principle. In some cases, proof of principle is not obtained and design / process direction needs to change which is equally valuable information. The first prototypes can also be extremely valuable for influencing colleagues, customers and managers to pursue a particular design or process direction when theory can be disputed at length. In the next article of the blog, critical design and process steps that lead to successful first prototypes will be discussed.

Bio:

David DiPaola is Managing Director for DiPaola Consulting a company focused on engineering and management solutions for electromechanical systems, sensors and MEMS products. A 16 year veteran of the field, he has brought many products from concept to production in high volume with outstanding quality. His work in design and process development spans multiple industries including automotive, medical, industrial and consumer electronics. Previously he has held engineering management and technical staff positions at Texas Instruments and Sensata Technologies, authored numerous technical papers and holds 5 patents. To learn more, please visit www.dceams.com.