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Process Makes Perfect

ASCO Valve's "Next Generation" product development process offers an interesting breakdown of design analysis factors.

By Lisa D'Agostini, ASCO Valve

Not long ago, ASCO Valve embarked on a product development project that entailed doing things which have never before been accomplished with a solenoid valve. And by redefining our design process, we developed features that improved performance and functionality, while also cutting costs.

Preliminary development of the Next Generation solenoid valve began in the late 1990s. In 2003, we kicked the program into high gear by re-evaluating the entire product design process. Our timeframe was 14 months, and at the end of each phase, deliverables were presented to an executive committee who made go or no-go decisions on the project.

The program goals were to:

- Develop a solenoid valve with expanded functionality that could be used in a broad range of applications.
- Include innovative features that exceeded anything on the market.
- Cost-effectively mass produce these new products.
- Maintain ASCO's reputation for quality.

We broke the entire process into a number of phases, with a primary focus on deeper scrutinization of the materials and components the new design would employ. This approach was based on our understanding that the new valve would have to improve operation without sacrificing reliability or robustness. To meet these conditions, our design process demanded greater definition and analysis of the valve's application conditions, which meant greater definition and analysis in the testing phases.

Meshing Performance With Design

Our four primary performance design criteria were:

- Meeting or surpassing the robust standards of the existing product line.
- Reducing power consumption.
- Operating with both AC and DC voltage.
- Increasing the ambient temperature rating to 140 degrees Fahrenheit.

The final two designs that were selected called for the integration of electronics, which had never been done before with a solenoid valve. This presented particular challenges that had to be solved at the concept development stage, such as printed circuit board (PCB) design, working with a new encapsulate material, implementing a new production process, and establishing quality and reliability assurance tests.

Detailed design reviews were held to concentrate on electronic packaging and electromagnetic compatibility, because the PCB layout needed to accommodate the most efficient and repeatable manufacturing processes. Additionally, since this was a new concept, PCB compatibility requirements had to be studied early in product development to ensure that the initial design concept could be modified as needed throughout. Identifying these types of considerations early in the design phase resulted in significant product life, reliability, assembly and cost reduction benefits.

In the new design, encapsulating material is used to protect the coil arrangement, which is the heart of the solenoid valve. Since coil design and manufacturing are core technologies, outsourcing was not an option. This meant the proper material had to be developed internally.

With this in mind, we expanded our team to include experts from Pennsylvania State University and E.I. du Pont de Nemours. The team evaluated three materials - epoxy and two thermoplastics.

Penn State offered knowledge and experience in using materials in production environments. They're production processing pointers also proved invaluable. The university conducted mold flow simulations, participated on site to assist in evaluation of injection molding machine settings, and suggested tools that would enable us to see required parameters (such as cavity pressure) during the injection.

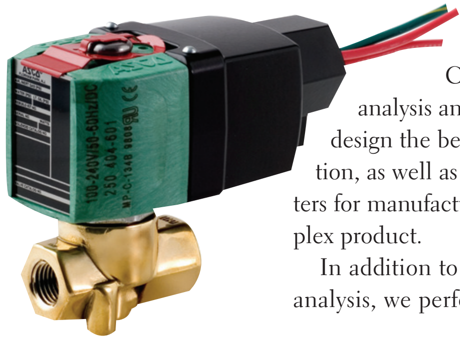
One of their recommendations, which proved key to the successful molding of the coil, was the integration of a pressure transducer to monitor mold cavity pressure. Because of the complex geometry of our over-molded part, maintaining a minimum cavity pressure for a defined duration was critical, and had a direct impact on the ability of the coil to perform in thermal shock testing.

Once the type of thermoplastic material was determined, we met with DuPont to analyze specific needs and actually develop it. A liquid crystal polymer (LCP) was selected that DuPont custom-formulated to match our parameters and UL requirements.

Putting It To The Test

While the LCP seemed to meet all performance and manufacturing requirements, it had never been used or proven in this type of application. Through the DuPont association, we were able to consult with other users of this material in non-competitive applications, which proved extremely helpful. For instance, ASCO planned to test an approach for adherence that one DuPont customer already had tried and abandoned.

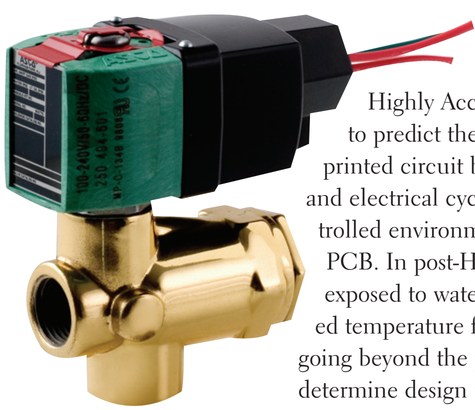
During the concept development phase, we required a capability analysis of the injection molding process. Thermoplastics offer some advantages over epoxy, such as less material waste, but the team needed to understand more



about the molding process. Comprehensive mold flow analysis and testing were required to design the best bobbin and yoke configuration, as well as to establish molding parameters for manufacturing repeatability of our complex product.

In addition to structural and mold flow analysis, we performed extensive stress tests to simulate actual working conditions in improving product reliability and service life in ranging environments. The challenge, however, was that there were no proven and accepted quality test procedures for this brand new product.

The unit's complexity, the application of electronics, a new encapsulation material and a new production process only added to these testing obstacles. We quickly realized that understanding the valve's performance required new analysis and verification methods, so we worked with accelerated life test experts to establish vigorous, yet realistic water intrusion and temperature cycling endurance tests.



The quality and improvements realized in ASCO's Next Generation line of solenoid valves can be directly attributed to a development process that incorporated a great deal of design analysis.

Our team decided upon a Highly Accelerated Stress Test (HAST) to predict the reliability of the internal printed circuit board. It consisted of thermal and electrical cycling of the product in a controlled environment to predict the life of the PCB. In post-HAST testing, the product was exposed to water intrusion tests with extended temperature fluctuations. This included going beyond the passing criteria points to determine design margin.

With two of our key performance parameters being ruggedness and reliability, both of which depend on the valve's ability to withstand temperature transitions, the team had to collect variable data in order to really understand how the product would survive rapid temperature transients over its lifetime. To do this accurately, the team focused on a couple of key design points.

First, they determined the root cause of variation. The fine points of ensuring that all manufacturing variations would yield the same performance were not something fully understood. Why were some coils surviving endless thermal shocks while others failed the first time? What were the key factors contributing to thermal shock success? Was thermal shocking the coil multiple times the correct test to determine the product's robustness over its lifetime?

The team also needed to understand more about the injection molding variations experienced with thermoplastic versus the epoxy material used in previous products. To address this issue, measurement tools were added to the injection molding equipment. This allowed additional parameters, such as cavity pressure, to be monitored and recorded. Overall, we had to determine viable options by establishing tests that would not just indicate if the product passed or failed, but produce variable data that could be used to determine root problem causes and process capabilities.

Double The Fun

After examining those components similar to each of the final two design concepts, the next step was subjecting each to focused analysis and testing to identify overall product reliability, costs and production requirements.

To clearly differentiate the two conceptual products, specific prototyping was critical. The traditional approach was to develop a prototype, test it, and if successful, assume it will always perform the same way. Since this was an unprecedented design, our approach implemented the use of more focused prototypes built to specific dimensions, produced by specific processes, and engineered to pre-determined limits.

The prototypes, which represented all variations of the final two concepts, were subjected to extreme testing; not just for functionality, but for failure. By testing to the ends of the spectrum, we determined factors such as anticipated variation from encapsulation processes, machining processes and from different PCB configurations. In addition to being tested to ensure a minimum life of 8 years, the prototypes also had to meet all the requirements for use in hazardous locations, which required accelerated testing methods. Repeatable manufacturability was also a consideration.

During concept design, development tests were conducted in a local facility with a controlled environment and highly skilled technicians. While this approach is acceptable for concept verification, it does not fully assess actual process conditions. So the next step involved producing and assembling the final product on the production line, including quality testing, to minimize product reject rate and line stoppage. To this end, products were produced and run through a battery of rigorous qualification tests in order to identify and reduce production variations.

With the development team overseeing initial production, the first product was produced and analyzed. All components were examined to make sure they met the required specifications. If a part didn't meet spec at this point, it would be a major problem that required retooling or end-product revisions.

Our approach to testing beyond required specifications ensured that product parameters and associated performance benchmarks were well detailed. Once an approved valve was produced, the baton was handed from the development team to the production team for full-scale manufacturing.

While the initial phase of intensive design engineering took a bit longer than usual, the prototype performed exactly as expected – with no surprises. This improved development time and reduced the costs of re-design work. The additional attention paid to design analysis and testing allowed us to introduce the RedHat Next Generation line of solenoid valves on time and on budget.

Lisa D'Agostini is New Product Development Director at ASCO Valve, a division of Emerson Industrial Automation Group. She can be contacted at ldagostini@asco.com.