Lessons in Manufacturing and Prototyping

Nicolas Avril - Enging.net - Blog 03 - August 2021

This blog series documents how I leveraged my manufacturing experience, materials science knowledge, mechanical engineering and prototyping skills to resolve real-life production or quality issues. The blogs are meant to crystallize the learnings, to educate, and to start conversations.

In the previous blog, we reported how, having identified and improved upon a weak point in the design of failing chair brackets, we casted polyester parts using a rubber mold. The next step was to test the parts for fit and function, but also to test their durability. This seems obvious for these brackets because someone could get hurt if they were to fail. But even when failure of the part does not risk causing harm, knowing when (and how) it will fail is important.

Figure 1. Polyester bracket installed (showing an angle mismatch (not the cause of failure))

The lifetime of a product can be expressed in number-of-cycles or hours of operation and should have been defined together with the other specifications. This specification (and the testing that accompanies it) is often misunderstood and as a consequence overlooked by junior hardware teams.

Because cycles are often in the thousands, a test rig might need to be built (even if one chooses to use a Highly Accelerated Life Test a.k.a HALT). A classic example are the test jigs made by the Ikea test lab (some of which can be seen in display in their stores).

The number of pieces to put to the test will be related to the level of uncertainty one can accept but also to the cost of the product. Here a balance sometimes has to be found between the quality and safety engineers (armed with statistical tools (such as Minitab)), and the product manager holding the budget.

And while exceeding these requirements by a comfortable margin is desired to avoid returns, high warranty costs, or dissatisfied customers, care should be taken not to increase the cost of the product with an over-designed part.

Often only a small part of a sub-assembly causes failure of the whole system. Spending the time to know which one it is will most likely pay-off by allowing for a more efficient solution. When some motors of the first version of the Roombas were failing prematurely, the team took the time to identify the root cause (a bearing). Replacing the bearing of a cheap motor with a high performance one was cheaper than buying a higher quality motor with a guaranteed longer life, and achieved the same result.

Back to our polyester cast chair brackets, we assembled a chair and tested it by sitting on it. It held but we noticed that the parts were bending to the point of coming into contact with the bottom of the seat.

We continued using the chair over the period of a week while making more parts (you want a statistically significant number of samples / test results). And as we were almost ready to claim victory, the first failures started occurring. The good news was that the failures were happening in a different location than on the original parts.

Figure 2. Failed polyester bracket

Using a fishbone diagram, we quickly identified design and material as the best characteristics to improve upon. Since we were not sure which approach would lead to the best result, and because testing all three options was relatively easy, we decided to pursue them all.

-Option 1- Increase the stiffness of the part by increasing the Young modulus of the material using different levels and types of additives (this might have been motivated by my expertise in materials science and composites). The main advantage was that this could be tested rapidly. Unfortunately the improvement was not sufficient.

-Option 2- Change the material type i.e. cast the parts in metal. Because we had not used rubber resistant to high temperatures, this was going to be a longer process. This approach was however given priority since it was almost certain this would results in good parts.

-Option 3- Increase the stiffness by changing the design in the base i.e. make that part thicker. This was relatively easy to do because of the position of the parting lines in the molds. A new mold was made but we decided to wait for the results on option 2 to use it.

The making and testing of the chair brackets out of metal will be the topic of the next blog of the series.