System Resilience –Toothpaste Capsule Dispenser

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Abstract

System Resilience (SR) is an important part of any systems approach; it serves as a method of verifying that the current design meets the project requirements. It is separated into two sections; *verification* which is about proving that the design meets the design requirements by developing and conducting a series of meaningful tests; and *prototyping and design communication* which involves exposing the system to the real world to receive real time feedback. This report also discusses an engineering case study on Scrap Rubber Tire Pad (SRTP) isolators that have the potentially to be used to stabilize homes in earthquake prone areas. This case study shows the importance of the early stages of SR in a systems development. SR can also be applied to the group project, the Toothpaste Capsule Dispenser (TCD) which has so far been developed using various systems approaches. By applying the prototyping and verification step the user's experiences can be fully understood. Using the systems design approach, the TCD design meets the client's requirements but by prototyping the design it is clear that some design changes are required to make the product more user friendly.

Background Theory

SR is an ever evolving process in system design that begins at the inception of a product and continues until the end of the products lifecycle. It allows a product to be defined and early concepts to be accelerated into a design phase with continuous modeling to provide constant feedback (Graham, 2000). Verification of a product involves developing meaningful testing which fall into five categories: analytical testing, proof-of-concept testing, model/prototype testing, operational testing and support testing (Blanchard, 2011). The project is only in its design and development phase, so only the first three tests are considered as these directly correlate to this design phase. The later tests relate to manufacture and the products life cycle which is not incorporated in the systems design approach. Analytical testing is important as it helps to provide a visual relationship of the systems (Blanchard, 2011). Care must be taken though as often mistakes can go unnoticed in analytical models and only appear when the design reaches production, which can prove to be a costly error (Graham, 2000). Proof of concept testing tests individual materials and systems to confirm they work individually, this doesn't indicate that the whole product will operate smoothly when the subsystems are combined. Model/prototype testing is the third stage of testing; it exposes the product to the real world and identifies problems that arise. According to Tom Chi (Leader of the User Experience Team at Google) model/prototyping testing is about finding the quickest path to experience the product, so that the designers can begin to learn at the speed of usage (Chi, 2013). The evolution of 3D rapid prototyping tools such as CNC milling machines has placed an emphasis on producing model/prototypes as they enable the designer to actually test the product in real time (Nafis, 2012). As testing proceeds its focus moves to results driven testing which quantifies the products abilities (i.e. stress-strain testing) (Blanchard, 2011). The final two types of tests are conducted during the manufacture and the products life. Operational testing is about quality controlling the manufacturing process and support testing is about continually checking and assessing the product to hopefully improve further designs and developments (Blanchard, 2011). The importance of SR to the system design approach is it provides a way to determine if the proposed design works, meets the customer requirements and can help to identify issues that are not apparent during other stages of the systems design approach.

Engineering Case Study: FEA and Experimental Verification of Scrap Rubber Tire Pad Isolator

This case study outlines the importance of SR in a products design phase. This case study shows the use of Scrap Rubber Tire Pads (SRTP) to help mitigate seismic movement of residential buildings by installation below a buildings foundation (Mishra, 2013). Using Finite Element Analysis software, stress–strain relationships were developed by simulating the SRTPs under loads (Mishra, 2013); these results were positive indicating that further experimental test should be undertaken. Experimentally the SRTPs were exposed to a series of mechanical tests (Mishra, 2013). These tests are the equivalent of proof of concept tests to help confirm if the product will sustain the stresses and strains that it would experience in its operating environment. The findings of these tests were also positive indicating that using the SRTP as low cost base isolation device for ordinary residential buildings is a feasible option (Mishra, 2013). This case study shows the benefits of using SR to design and test a product; the SRTPs mechanical properties are analyzed without the huge expense of implementing them into a real life situation to test them. If the experimental results had not been satisfactory the design team would have been require to implement a change in design (Blanchard, 2011). The next step of SR would require the design team to expose the SRTPs to an earthquake simulation to determine how the system would cope. Continuous testing of this product would be required to ensure that it works effectively before its commercial release. This case study highlights the important testing steps in SR.

Application of the Theory to the Capsule Toothpaste Dispenser

The case study highlights the importance of proof of concept testing and prototyping, which can be applied to the Toothpaste Capsule Dispenser (TCD) to help outline design issues and improve the product. The TCD is still in the systems designs phase so only the first three tests specified by Blanchard (2011) are applicable. The first step is to develop what aspects of the system require testing. By analyzing the current design, customer requirements and cascade attributes, appropriate tests can be formulated for the TCD (*Table 1*).

System Aspect	Verification Tests
TCD dimension.	The measurements of the TCD can be tested using analytical testing. The product can be rapidly designed in analytical software with a visual representation of the various systems present and how they interrelate. Multiple designs with different shapes and sizes can be developed and simulated rapidly to determine the optimum shape and aesthetics for the product.
TCD mechanism.	The mechanism in the TCD should be tested through all three testing phases (analytical, proof of concept and model/prototyping). This mechanism must be tested to ensure it works reliably and no issues will develop as a result of continuous use of the product. As the TCD uses proportioned capsules, the mechanism must only regulate the release of one capsule per usage.
Capsule activation/ Water activation.	The concept of the capsulated toothpaste comes from commercially available pharmaceutical drugs with film coatings that break down on the addition of water/saliva (Film Coatings). The modeling/prototyping of the product would involve collaboration with a pharmaceutical company to ensure that the product is safe and activates on addition of water to release toothpaste.
Client usage.	The client's actual usage of the product must be considered. When meeting with the client it was noted that the client has poor motor control skills and an obsessive compulsive disorder (OCD). Model/prototype testing of the TCD using this knowledge will help to understand how the user will interact with the system and the issues and complexities that may arise as a consequence.
TCD mount	As per the customer requirements the unit must be a wall mounted system. The mounting systems must be tested to determine an appropriate mount that ensures the safety of the user. It can be tested using analysis and model/prototype testing.

Table 1 – Systems Aspects of the TCD and Verification Tests.

To apply the theory of SR to the TCD, the tests developed during the verification steps (Table 1) should be conducted to determine whether the current TCD design will be successful. Using solid works a 3D model of the TCD was created which helped to highlight the links between the interrelated systems (see Appendix 1). The product was also modeled/prototyped to simulate the usage of the product by the client (see Appendix 2). The conclusions and feedback from these tests are highlighted in the discussion.

Discussion

By applying the theory of SR to the TCD it is possible to observe problems that arose from the current TCD design. These problems can then be resolved with appropriate design changes. Analytically testing the product, it is clear that the TCDs dimensions, mechanism and mount are all strongly correlated. Changes to one of these three systems have flow on affects to the other two systems, for example: *if the TCD mechanism is to change the dimensions will change to fit the mechanism and the mount must be stronger to support the whole system.* This highlights the continuous nature of testing and the way feedback influences changes in the design (Blanchard, 2011). It also highlights how proof of concept testing supports these systems individually but care must be taken for modeling/prototyping to ensure all systems work together efficiently (Graham, 2000). The mechanism is designed to deliver proportioned capsules, thus the three systems will be greatly influenced by the size of the capsules and the amount of capsules that the system must hold. To be effective it was estimated that the system would require at least 30 capsules. This places constraints on the design, which feedbacks to the design of the mechanism and the holder components.

The testing of the capsule activation highlights the problems that will be involved to get this system working efficiently in the product. It is clear that collaboration with a pharmaceutical company for the production of the toothpaste capsule is necessary to ensure that the product safe and usable. It also highlights the issue that the capsule must be kept dry until released. These issues can be addressed by appropriate design changes and consultation with an expert in the pharmaceutical field.

The final and most important aspect that needs to be tested is the ability of the client to use the system. At the client meetings it was determined that the client has poor motor control skills and an obsessive compulsive disorder (OCD). By rapidly prototyping the system with common materials to experience the system it comes clear that holding the toothbrush still and pressing the mechanism at the same time may be quite difficult for the client. For this reason the system should be moved away from a push mechanism design to an electronic sensor design which activates the mechanism when the toothbrush is inserted. To help stabilize the toothbrush whilst the toothpaste capsule is being applied a holder mechanism is required. Another issue that becomes apparent from using the prototype system is the importance of a locking mechanism. The clients current OCD involves emptying toothpaste tubes. Without a locking timed mechanism it is likely that the client will attempt to empty the TCD. A timed locking mechanism will need to be incorporated into the system to prevent this happening. It is clear that using SR has highlighted some of the TCDs design issues. By changing the design to fix these issues we can go back through the system design process for the new product, for example the development of a revised functional block diagram(FBD) (see figure 1).

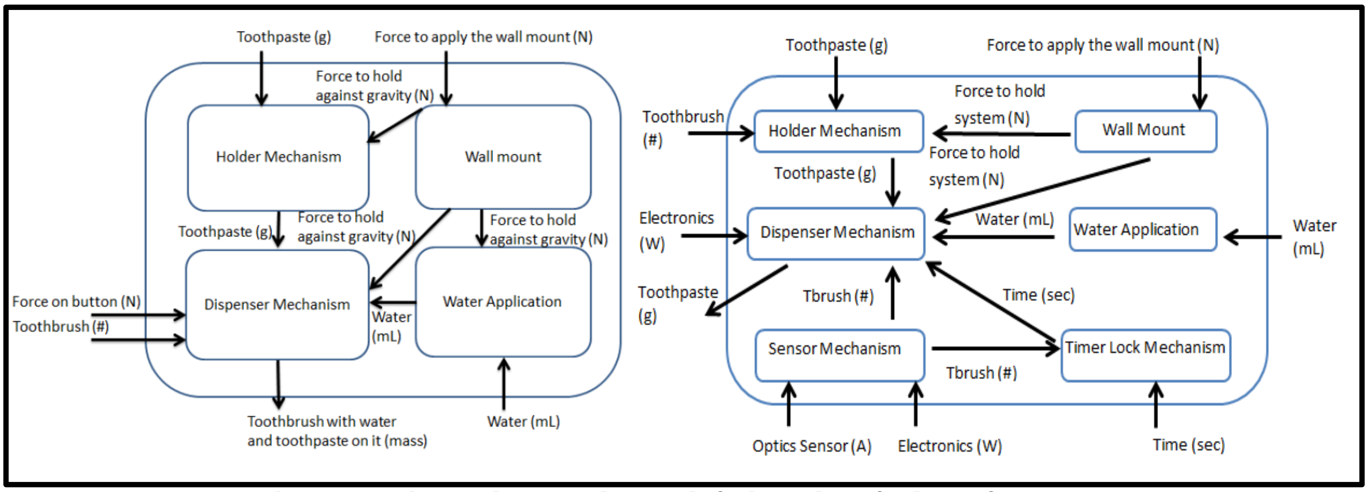

Figure 1 –Original FBD (right) and Revised FBD(left) based on findings from SR.

Applying SR to TCD we have developed an updated FBD. It is apparent that the systems design approach should be applied continuously to analyze each design until the best design has been developed. Without the SR step it can become costly and difficult to rectify design issues once we have moved on to the production phase. Using the SR approach the issues regarding the TCD design have been identified and appropriate changes made to make the product more user friendly. This process would then be conducted on each new design until the final design has been developed.

Conclusion

System Resilience is a vital tool for testing and prototyping when developing a product. It enables a designer to receive feedback about a product during its design process and identify issues early, enabling them to be rectified. The SR systems approach highlighted that the TCDs current design meets only some of the client's requirements, but several issues where highlighted during prototyping reflecting a change in the design.

References

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Appendix 1 – Solid Works Design

Using Solid Works the TCD was analytically tested. The first design although simple, helps to outline the complex nature of each component and the links between systems (see discussion). Since the design is still receiving feedback from various tests, the analytical TCD can be rapidly updated to reflect changes in the design. The TCD was developed in three components; the casing, the dispenser and the holder. These subsystems can also be subdivided as more complex designs are required. As the system is changed the simulated design can be rapidly revised making it a quick and easy way to develop the design.

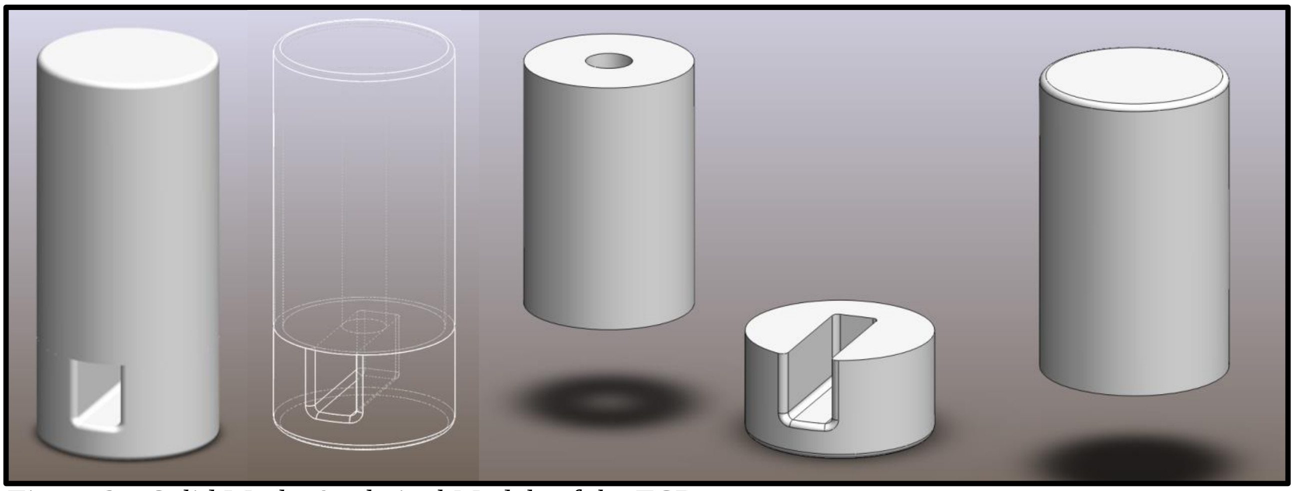

Figure 2 – Solid Works Analytical Models of the TCD.

Appendix 2 – Modeling/Prototyping Testing

The TCD was also rapidly modeled/prototyped using a cylinder attached to the bathroom wall. By inserting a toothbrush and manually pressing the system to simulate activating the mechanism it was discovered that that it would require fine motor control skills to complete this task. It was also discovered that it may be possible for the system to be activated multiple times releasing several capsules resulting in wastage of capsules or the system becoming clogged by the capsules. Since the user has poor motor control skills, it is clear that some design changes are necessary; these can be found in the discussion.

Appendix 3 – Peer Review

Aleksander Varga : Demonstrates that formatting requirements have been met.

It would be recommended that the headers and footers are taken out from the paper because it doesn't relate to the formatting requirements which may hinder marks. Also centering the descriptions of the tables/figures will make it look a lot neater and balanced as displayed in table 1. The indentation also has some discrepancies, in the bibliography it makes it hard to read and the start of background theory has two tab indentations instead of one. The spacing, use of fonts and all other aspects seem to be well within the guidelines specified.

Aleksander Varga: Demonstrates a correct understanding of the theory:

Going into more detail sooner about why only the first three tests are needed would give early clarification even if it is described later on in the paragraph, this would be useful and increase the flow of the background. Also, maybe talk a little about what the last two tests are; you've stated when they occur but a little information into what they do/processes they undertake would be beneficial. In the case study the phrase "The study studies" is a bit difficult to read, try altering the words to 'The case shown studies' or something similar.

Aleksander Varga: Application of the theory to the project.

Within the table and thereafter you label the TCD as the TCD. Overall through the application of the project there was thorough use of the application to the dispenser and how/what is done to prototype the product.

Aleksander Varga: Quality and relevance of bibliography.

Quality in text referencing is used throughout the paper with all credible and reliable sources. The only trouble is regarding the formatting of the bibliography in which it makes it slightly hard to read.

Aleksander Varga: Suggestions on how could the paper be improved.

There are some grammatical errors and a few typo's within the draft, a few examples of these include lines 4 and 6 of the abstract where it should be 'tests' and 'of' shouldn't be included, etc. So a quick 10 minute proof read would help fix those minor problems. Within the case study you're also stating 'they would' instead of 'they have', have they done this in the case study or are certain aspects theoretical?

Other than the few grammatical errors and the application of headers and footers to the report, it seems to be informative and well balanced. Keep up the good work!

Dylan Conolan: Demonstrates that formatting requirements have been met.

All looks pretty good. Maybe make the references left aligned to make them easier to read. (not sure if you are allowed to do this or not). Add some more paragraphs in there to break up the large blocks of text.

Dylan Conolan: Demonstrates a correct understanding of the theory:

Good amount of sources and referencing of them throughout the paper.

Dylan Conolan: Application of the theory to the project.

Understanding was very comprehensive, good job.

Dylan Conolan: Quality and relevance of bibliography.

No Comment

Dylan Conolan: Suggestions on how could the paper be improved.

There were a lot of references throughout the paper. Not sure whether these were quotes or your interpretation of information from those papers. If these were all quotes, perhaps try and rephrase them into your own words. If not, good work.

After consultation with Chris Browne I was suggested that I write my feedback of the usefulness of each peer reviewer to highlight any changes I made from their comments. Aleks peer reviews was generally helpful to my final report. Aleks comments highlighted a few issues with general structure and flow and highlighted that some improvements with respect to grammar which helped to improve the report. He also highlighted that I didn't thoroughly explain what the final two types of testing which I rectified in my final report. Dylan's comments were somewhat vague and unhelpful. He made comments regarding my formatting and bibliography but no comments about the actual report. I was unable to use his comments to improve the report as did not comment on the application and understanding of the theory in the appropriate sections.