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Department of Mechanical and Mechatronics Engineering

ME100: Toy Design Project Report

A Report Prepared For:
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Mollie Jameson
Spin Master Ltd.
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Good day Ms. Mollie Jamison,

This report, titled ME100: Toy Design Project Report, was made because of our design project deliverable for the course ME100: Introduction to Mechanical Engineering Practice 1. Through this report, the hope is that you would understand the idea of the toy and the concepts, inspiration, and engineering work that went into developing the toy thus far.

Our project, named The Plunge, is a toy designed for children 8-14 who cannot sit still and need something to help them focus. We based our toy on the popular fidget spinner and modified it to give the user a more satisfying experience. The toy borrows the design of a salad spinner plunger and implements it into the fidget spinner so that the toy can be spun with the depression of the plunger. The plunger is made to give a stress-relieving feel and the user can experience the joys of fidgeting with a rotating body and a well-adjusted plunger at the same time.

We expect The Plunge to be popular amongst its target age group as it is a fun and enjoyable toy while inexpensive and it would be a powerful addition to Spin Master's toy lineup.

This project was completed solely by the students who signed below and has not been turned in for credit at the University of Waterloo or any other institution. We thank you for taking the time out of your busy day to review this work and if you have any questions, comments, or concerns, please feel free to contact any of us.

Best Regards

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Summary

The process of ideation for the plunge comes from taking a widely celebrated toy and building upon its pre-existing features. “The Plunge” uses the fidget spinner as a base, and through the addition of external components creates a unique experience compared to the average spinner.

The Plunge is a toy that has a sensory play pattern, engaging different senses of the user. It has an age group of 8-14, but it is suitable for play for those of all ages. Products comparable to The Plunge include the OXO Salad Spinner, clickable pens, Fidget Cube, Pop It, and other toys that follow a similar play pattern. Research done by the World Health Organization in 2013 shows that purposeful fidgeting increases the neurotransmitters that form the basis for an individual's attention span, thereby increasing their focus [1]. The Plunge is a purposeful fidgeting device that strives to provide a way for children to focus on situations by giving their minds something to partly focus on. This report's objective is to determine the viability of the idea outlined above and to discover if the product is possible to manufacture.

The function of the toy makes use of a press, spring, drive shaft and an inner core with a counter-directional locking mechanism. The user pushes down on a press which allows a drive shaft to go down and interact with the coils of the inner core. There is a counter-spin mechanism once the drive shaft moves downwards which allows the inner core to lock with the outer core. This allows the spinner to continue rotating in the same direction, allowing the user to experience a smooth feel upon releasing the press.

Many mechanisms in the prototype version of the toy could be further tested and redesigned to improve user experience. This includes finding a spring with the ideal strength or providing the exact spring force so the drive shaft can return to its original position in ample time for the user to press upon it again. In addition, there is work to be done on finding a way in which the drive shaft can be better centred, improving user experience by creating a smooth press-release motion and increasing the play cycles for the toy.

The Plunge is a viable toy that will have a large audience. Recommendations include testing and exploring different components that will improve the stress-relieving feel of The

Plunge and finding different methods of manufacturing as mass 3D printing parts will be costly and time consuming. Lastly, exploring efficient methods of combining parts, as currently an adhesive is used to combine the outer core to the ball bearing.

The essential concept of The Plunge is simple yet appealing. By adding a few new features to the common fidget spinner, a unique fidgeting toy is created. This toy has much potential and can be seen as a favoured product for its target audience. With more testing and improvement on the toy's engineering design, the Plunge can be seen as the predecessor of other toys of its kind.

1.0 Introduction

Like other toys of its kind, the Plunge functions are based on simple mechanisms. It has an easy-to-follow play pattern that is simple and enjoyable.

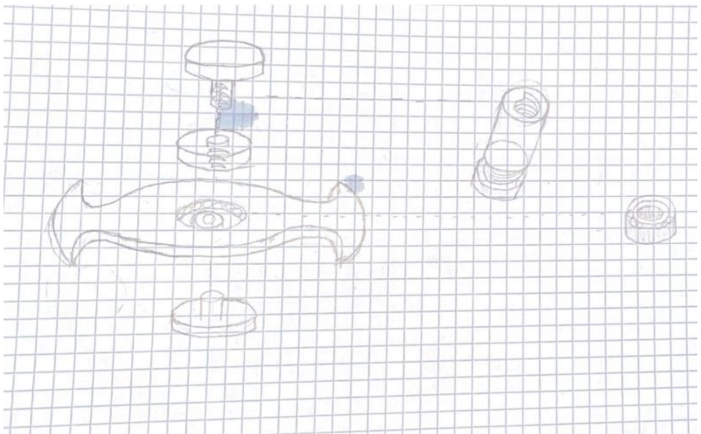

Figure 1: The Plunge Concept Sketch.

The Plunge is a modified fidget spinner with a plunger allowing for rotation of the spinner to be achieved through the depression of the plunger as shown in Figure 1. This toy plays off the idea of the OXO salad spinner and others like it. Much like feet tapping or pen twirling, people have an unnatural attraction to executing a rhythmic repetitive task at consistent intervals. The Plunge plays off this attraction in hopes that individuals will feel the need consistently press on the toy. The toy is satisfying, anxiety relieving, and is a fun fidgeting device for children and teenagers to help keep their minds focused on the task at hand, much like the purpose of the original fidget spinner and other fidget toys like it. “If [the children] are playing with a fidget spinner, or tapping with a pen or a pencil, it automatically forces their brain to work harder. The brain must put more effort into not being distracted” [2].

1.1 Play Pattern / Age Range

The Plunge is marketed towards children from ages 8-14 years old. The age range is set this way because it imitates the way that fidget toys are positioned in the toy market [3]. As children this age benefit the most from the play patterns, it is logical to design the toy specifically for this range. The Plunge has a sensory play pattern primarily engaging two of the five senses. The first sense The Plunge stimulates is sight. The spinning motion of the fidget spinner allows the user to have another object to look at. As the brain works harder to process the user's current tasks and the new visual stimulation, more attention will be put on the other tasks [2]. The second sense the toy engages is the sense of touch. The toy uses a vertical pressing motion to allow the fidget spinner to spin. The sensation of pushing down smoothly with a controlled amount of force, coupled with the spring mechanism of the toy gives the user a temporary relief of stress due to the controlled input of stimulation [4].

1.2 Comparable Products

Figure 2: OXO Salad Spinner [5]

Figure 3: 608 Ball Bearing [6]

The Plunge can be seen as a coalescence between a salad spinner and the fidget spinner. It uses the mechanisms that allow an OXO salad spinner (Figure 2) to spin and integrates this mechanism with the bearings of a fidget spinner (Figure 3) to allow the fidget spinner to spin manually without direct contact. The Plunge is also like a traditional pen in the sense that it borrows the direction-locking mechanism later discussed in section 3.1. In addition, the Plunge sits in the same market as other fidget toys such as the Fidget Cube, Pop It, and many others due to their ability to provide a distraction from certain anxiety symptoms [4]. The Plunge is set apart from these other fidget toys however because it uses a unique mechanism in the plunger to accomplish a simple task in spinning the fidget spinner. The other toys are quite simple, but The Plunge uses mechanical design to turn a simple toy more complex to achieve its goals.

1.3 Objective

The objective of the report is to determine and prove or disprove the toy's feasibility. This conclusion is based on the ideation, constraints, and technical development of the toy.

2.0 Problem Definition

This section examines the problem of how to efficiently turn a linear force applied from one's hand into a centripetal force, without direct contact from said hand. 2.1 talks about what the required functions of the solution are and what it must do while section 2.2 discusses certain constraints put on the design to test whether the design is successful. In addition, 2.2 adds criteria that The Plunge can be optimized for and how the toy ideally functions.

2.1 Required Functions

The Plunge's principle required function is to have linear motion be converted to rotational motion resulting in the rotation of the spinner consistently. Another required function for the toy is that the plunger must automatically reset itself after each depression so that the next plunge could occur easily. If it does not accomplish this, then the toy would be considerably harder to use and play with. The durability of the spinner is also a required function; the components of the toy must endure the force asserted on it upon being pressed on.

2.2 Constraints and Criteria

Many constraints are considered throughout the design of the toy. Assessing the extra components added to the spinner, the toy can reach up to 300 rpm. This was defined using the typical speed of a normal fidget spinner (420 rpm) [7], and by considering the constraint of extra weight added to the spinner and a rotating mechanism being used to spin the toy instead of manually spinning with the hands. Factoring in the target age group of the toy, the length from one prong to another is set to be 80 mm (about 3.15 in) [8] with a height of 60 mm, this was considered so that the toy would be compatible with the average hand. The mass range is determined by using the average mass of a regular fidget spinner (50 - 90g) [9], factoring in additional mass for the rotating mechanism, The Plunge should weigh toward the heavier side of this range.

One of the main criteria considered through the design process is to minimize friction within the spinner. Reducing friction between the thread and the shaft will give the spinner a smooth release, aiding the stress-relieving feel of the spinner. Overall reduction of friction throughout the toy can also aid with giving the spinner a better spin duration, top speed, and overall experience of using the toy.

3.0 Technical Progress

In section 3.0, the overall technical progress is discussed. Firstly, in section 3.1, different solutions are discussed to meet the required functions, constraints, and criteria of The Plunge. In 3.2, all of the documented progress is displayed including images of the initial prototypes, what was discovered, and improvements made towards the next prototype, and in section 3.3 the remaining challenges to continue with the design of this toy are discussed.

3.1 Solutions Considered

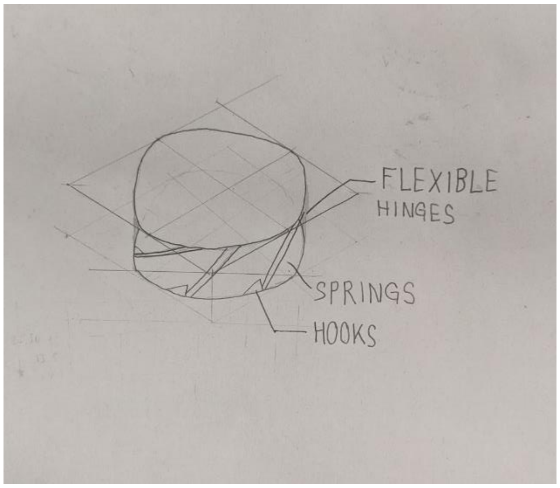

Figure 4: Spring Steel Hooked Design

For the function of turning linear motion into rotational motion, two different solutions are considered. The first solution considered is a spring steel hooked design. The springs with flexible hinges are attached to the upper cap (Figure 4) and as the plunger goes down, these springs push on hooks in the lower cap, turning the lower cap which is attached to the outer edge of a ball bearing. This mechanism spins the fidget spinner and achieves the function. The springs are horizontally rigid but vertically flexible allowing for the springs to reset for the next plunge.

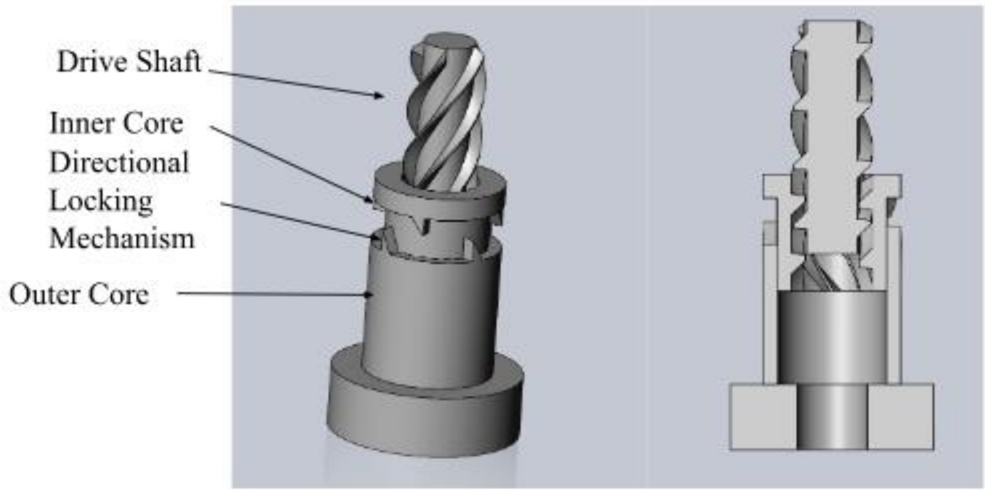

Figure 5: Plunger Mechanism CAD Render

Figure 6: Pen Mechanism

The second solution draws its inspiration from the design of a salad spinner and clickable pen. Figure 5 shows the four main components of the design. The drive shaft goes down and interacts with the coils of the inner core to turn it counterclockwise. As the inner core spins counterclockwise, it locks with the outer core via the directional locking mechanism (DLM). The DLM draws the design from a pen. In Figure 6, the inner white part of the pen only rotates one direction due to a triangular piece of plastic interacting with it after each click. As the driveshaft returns to its original position to reset, the inner core rotates clockwise but due to the DLM the outer core remains spinning counterclockwise and thus one direction motion is achieved through linear motion.

For the initial prototype, the second design is used because it is simpler to implement and easier to manufacture compared to the spring steel hooked design. Some pros of the spring steel hooked design are that it does not rely on gravity and thus would work upside down. Additionally, it would be less bulky and take up less space due to it having fewer components. The benefits however do not outweigh the challenges of manufacturing such a mechanism and the spring steel hooked design is overall too complex. The flexible hinge system is fragile and sourcing small spring-like pieces of steel to fit the constraints is not easy.

Another required function discussed is the automatic resetting of the plunger mechanism. There are a few ways to accomplish this, but a spring is the most trivial. A spring enacts a restoring force on the drive shaft so that it can successfully be returned to its original position. There are many springs with dissimilar spring constants that all affect the user experience. 2 styles of spring are ultimately considered for The Plunge. The first spring is a spring that fits outside of the outer core and the other is a spring that fits within the inner core. A spring that is wider in diameter can provide a larger spring constant and help optimize the satisfactory feel of the plunger; however, a spring of that specification is harder to source compared to one that might fit inside the inner core. Simple springs found in pens can be used albeit not as strong as the larger springs, it accomplishes the required function.

3.2 Progress to Date

Before the manufacturing of the first prototype, a salad spinner is taken apart to understand how its mechanism works. The OXO salad spinner effectively transforms linear motion into rotational motion and allows for the compounding of energy within the basket. The salad spinner uses a threaded metal rod to spin an inner core and uses similar directional locking mechanisms to keep the basket spinning in the same direction as the plunger resets. It also uses a thick lubricant to reduce friction between the inner core and the threaded metal rod.

Ahead of creating the first prototype, different manufacturing methods are considered and 3D printing is used due to ease of manufacturing. The 3D printer prints exactly according to instructions and although more expensive and not suitable for mass production, it is great for spotting mistakes and looking for improvements in the design. Injection moulded plastic is also considered, however, the challenge there is creating the mould detailed enough to model the parts needed for the plunger. The pieces of the plunger mechanism end up fine and creating them would be difficult using this method. Many types of filaments are considered, and the main ones considered are ABS and PLA. PLA plastic is cheap, made of organic material, and has an exceptionally low carbon footprint. There are many pros to using PLA plastic on a large scale however, PLA is more brittle compared to ABS plastic and ABS is less rigid, tougher, and lighter, making it a better plastic for prototyping applications [10].

Figure 7: Plunger Mechanism 3D Print V1

Figure 7 shows the first prototype of the plunger at a 2x scale. The first prototype is made in a 2x scale to ensure that the overall design works. Being such a small mechanism, it is hard to know what works and does not work from the CAD file. A 2x scaled prototype shows that the pieces fit together and that the thread angle is sufficient for the function. After testing and evaluating the first prototype, it is noted that there are not enough DLMs as it would take the entire rotation of the inner core for the two cores to lock together. This decreases the efficiency of the plunger mechanism and decreases the maximum speeds that the fidget spinner can reach. To get closer to the constraint of 300 rpm, more DLMs are added to increase efficiency and preserve the force from linear to rotational conversion.

Additionally, the DLMs on the inner core and the outer core are not the same height in the initial prototype. With different heights, it changes the angle of the ramp and how the two mechanisms interact with each other. It is noted that the linear to rotational motion's efficiency is not as high as needed for the toy because of this reason. They are made equal in later prototypes to increase efficiency and reach a higher spin rate. Otherwise, the design successfully transforms linear motion into rotational motion at a 2x scale.

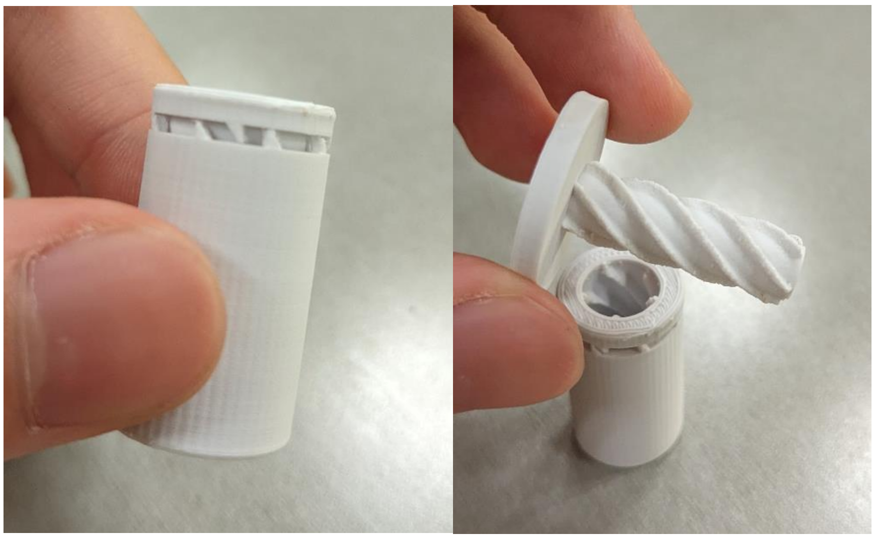

Figure 8: Plunger Print 3D Print V2

Taking the information from the first prototype, many improvements are made to the plunger mechanism and printed in 1x scale. A top cap is added (Figure 8) to the drive shaft so that the drive shaft would have a stop and something to push down on while using the toy. In addition, the outer core is made to be longer to fit the sizing constraints listed in section 2.3. In a 2x scale, the outer core size is sufficient for the 60 mm constraint; however, when scaled to its intended scale, it is not long enough. For this prototype, the outer core is adjusted to be 29 mm so that the entire height including the bearing and drive shaft top cap summed up to around 55 mm.

Additionally, at a 1x scale, the threads are rougher than in the 2x model. This is due to the width of the extruded plastic in the manufacturing process, and the threads are sanded down to allow minimal friction between the drive shaft and the inner core to maximize efficiency and reach the 300-rpm constraint.

From this prototype, the pen spring is put inside the inner core to be depressed by the drive shaft however it is noted that the spring often came out of place and moved laterally instead of remaining in a vertical orientation. In testing, this displacement of the spring failed in the function of returning the drive shaft to its original position. A guide is made in further prototypes so that the spring remains in its intended orientation.

Lastly, from the second prototype, the inner core is too short for repeated plunges. After each depression of the plunger, it would come back up to reset however since the length of the core was short, it came out of the outer core slot and would often not go back in. In future prototypes, the length of the inner core is increased to allow for more play cycles.

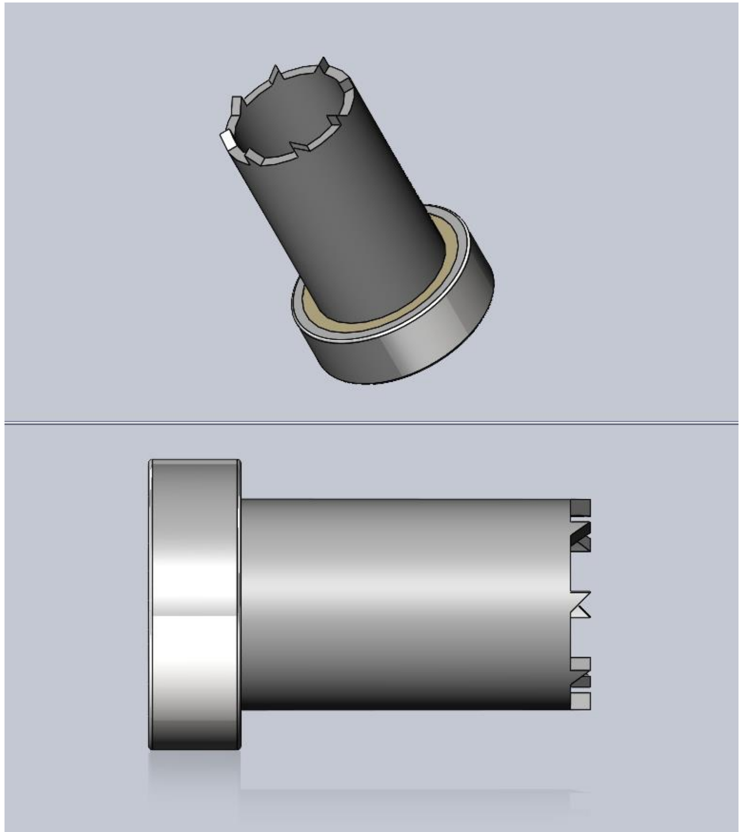

Figure 9: Ball Bearing Outer Core Connection

Figure 10: Plunge Prototype V3

In the 3rd and latest prototype of The Plunge, the outer core is connected to the bearing with super glue which allows the bearing and outer core to spin simultaneously (Figure 9). There is a cap that houses the ball bearing while keeping dust and debris outside. The outer core is connected to that cap. Super glue is chosen as the bonding agent since it is quick curing, cheap, intuitive to use, and long lasting.

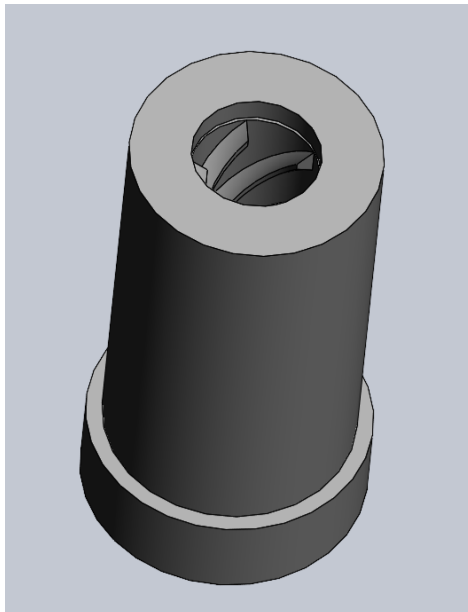

Figure 11: Updated Inner Sleeve CAD

Inner and outer sleeves (Figure 10) are also added to house the components and keep everything in place. Without it, the inner core has an even higher tendency to come out of the outer core socket. Adding the sleeves and increasing the length of the inner core reduces the tendency for the plunger to suddenly stop working. One more component that will be added in future models is a mechanism to stop the inner core from rising too far up within the resetting of the plunger (Figure 11). As of now, the inner core is free to rise as high as it wants and if it does not surpass the length of the inner core, then it remains in the socket. A mechanism can be added to ensure that the inner core stays at a certain height and as it approaches that height, it will rotate off more instead of continuing to rise.

From the testing of the spinner, the mechanisms are shown to work quite well together reaching high speeds of around 250 rpm as measured with a high-speed camera and a piece of tape on the spinner. This is well in the constraint set previously. It is noted that with very harsh play, the DLMs of the outer core break off easily. This issue is a result of the thickness of the component and material used.

Figure 12: Broken Outer Core

With a cover to keep debris out of the ball bearing, the overall plunger mechanism continues to function due to the redundant number of DLMs designed into the outer core (Figure 11). Even with 2 of them broken off, 6 more remain, and as long as all the DLMs do not break off, the plunger mechanism continues to function, though less efficient in transforming linear to rotational motion.

3.3 Remaining Challenges

One of the remaining challenges is finding the right spring for the plunger mechanism. The spring needs to be within certain constraints because the rest of the plunger mechanism is built to certain dimensions. The spring must be no greater than 8 mm in diameter and around 35 mm in length to allow the drive shaft to fully return to its neutral position. If all these constraints are met, there is one final constraint relating to the spring constant of the spring. The spring constant here must be low enough that it does not prevent the user from pressing down on the plunger but at the same time must be strong enough so that the drive shaft will return to its neutral position. Optimizing the satisfactory feel relating to the spring constant is an immense challenge.

From the prototypes, it noted that ABS plastic is not the most durable of materials, especially for the finer and more delicate parts of the plunger mechanism including the directional locking mechanisms. Finding suitable materials will be a challenge as most metals will be difficult to manufacture on such a small scale and accuracy with the given prototyping methods.

The last anticipated challenge is maximizing the stress-relieving feel of the plunger. People have different preferences for the strength of the spring constant and to maximize the satisfaction feeling for everyone, testing must be done to capture the consensus. Once testing is done with many different prototypes, the final product can be decided on.

4.0 Conclusions

This section of the report details the answer to the overarching question: is this toy feasible? In section 4.2, more recommendations are made for continuing the development of The Plunge.

4.1 Conclusions

After much testing and technical progress, The Plunge is a viable toy idea and can be extraordinarily successful if further improvements were made. The main function of the toy is for it to convert linear motion into rotational motion and the toy successfully accomplishes this task regardless of the current efficiency. The greatest challenge in accomplishing the main function is finding a way for the linear motion to result in a directionally locked motion. Two solutions are considered to convert linear motion to rotational motion. The first is a complex spring steel hooked design, and the second design draws inspiration from a salad spinner and a pen. The second solution is chosen due to the simplicity of the design and the proven nature of the products that they come from. Concepts and designs are borrowed from trivial products such as the common pen and as these innovations have already been made, only adjustments need to be made so they can be implemented into The Plunge. Overall, the toy shows the potential for refinement and optimization to become an entertaining and stress-relieving toy for children and is deemed viable.

4.2 Recommendations

For further development of The Plunge, the stress-relieving feel of the toy should be optimized. A survey should be conducted to test diverse types of components and their effects on the user experience. The main component to interchange and test here is the spring as different springs have different spring constants and that factor will change the user experience.

Additionally, more efficient methods of manufacturing should be explored as 3D printing at such a small scale is difficult and takes a great deal of time. The ABS filament used to create the initial prototypes is also not the strongest of materials so looking into alternative materials for manufacturing would be beneficial. Some prospective materials include injection moulded plastic, aluminum, and others.

Lastly, the implementation of the plunger mechanism on the fidget spinner should be improved. Currently, super glue is used to attach the outer core to the bearing of the fidget spinner; however, superglue is not exceptionally durable and cannot withstand lateral force well. A stronger bonding method is preferred and if a material such as aluminum were to be selected for the plunger mechanism, then welding could be a potential solution.

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