Design for Manufacturing, Reliability, and Economics

EML 4551C – Senior Design – Spring 2013 Deliverable

Active Surface Shaping for Reflectors

Team # 9

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Manufacturing

In order to create a prototype of the adjustment mechanism in the most efficient manner, the team had to consider various manufacturing processes when designing the mechanism. Considerations were taken to help reduce the overall production cost, minimize the complexity of the manufacturing, and acknowledge that there was a limit on product tolerances by the necessary manufacturing processes.

Material Selection

Before the mechanism was designed, research was done on the best available materials to construct the mechanism that would provide an economical design. With aluminum and acrylonitrile butadiene styrene (ABS) plastic under careful consideration due to their lightweight properties and availability, it was determined that ABS plastic would be the best material for the primary components of the mechanism. ABS plastic is used as the generic 3D printing material, which provided a low density, durable, and cheap material that is used to print the complex structures of the mechanism base.

The materials of other essential components for the mechanism to be selected were for the 4-40 all thread rod, gears, and washers. Aluminum was selected for the 4-40 all thread rods because of its lightweight material properties and availability from McMaster-Carr. Brass was selected for the drive system that consists of the gear and pinion due to its weight, cost, and durability. Low friction, nylon spacers were added between base and gears in order to reduce wear on the base of the mechanism from the gears. Utilizing these shims also eliminates possibilities of foreign object debris (FOD), a major concern in the aerospace industry, from the gears wearing away the base material.

Materials for the visual demonstration consist of 80/20 aluminum beams for the frame. This material was chosen since it is sturdy which will aid in accurately displaying measurements as well as it is more aesthetically pleasing and offers a professional look. Non-stretch braided fishing line will be used as a substitute for the typical quartz cord used in reflector adjustments. This was done in an effort to reduce cost and decrease lead time for demonstration purposes.

For the electrical systems to be integrated onto the mechanism, a perma-proto board was selected in order to compact the overall design and further reduce weight. The microcontroller selected to control the motors was the Arduino Nano as it's an open source platform, pre-existing background in C programming, and its compact size. The TI SN754410 motor driver chip was utilized due to availability, ease of use, low cost, and small size. Motor selection was based mainly on size and required torque. As a result, the Faulhaber AM 1524 stepper motor was the logical choice.

Manufacturing Process

With the complex shape and curves in the geometry of the adjustment mechanism base, a specialized process would be necessary to create the base. So in our case, the 3D printer was ideal due to the material that it printed with, along with the available resource of a Dimension SST 1200 3D printer located on the campus.

Other components on the mechanism to be machined were the 4-40 all thread rods that needed to be milled flat on the top and bottom, along with the gear stock that needed to be lathed down into thinner pieces to fit within the mechanism base.

The 80/20 aluminum beams used to build the tabletop visual demonstration for the open house were cut in order to fashion a cubic frame. Once pieces are cut, they will be fastened together using associated L-brackets and t-head bolts and nuts

Manufacturing Location

The machine shop on campus was unsuccessful in the initial attempt to get the 4-40 all thread rods milled flat on the top and bottom of the thread. They encountered many problems that included the thread popping out of the clamps, bending of the threads which gave it an uneven profile, and ultimately broke. After informing the sponsor at Harris of our problem, they offered to machine these parts for us. With allocated funds for the senior design projects with special circumstances, Harris's machine shop was able to provide them at a cost of $100 each.

The gear stock was submitted to the machine shop on campus which lathed it into thinner pieces useable for the mechanism. The base of the mechanism, along with other components were printed on campus as well with the 3D printer.

The visual display will be built at Cameron Duncan's shop at his home, with access to metal band saws, a tungsten inert gas (TIG) welder, and various other machines will allow for adequate and timely construction of the display frame. Brackets for string potentiometers will also be fabricated there and the display will be assembled in its entirety on-site.

Product Specifications

Our sponsor has explicitly stated the objectives our team must achieve. We are to build one automated, high precision adjustment mechanism. This mechanism is to be used as a visual demonstration model for the open house that must be able to measure the displacement of the cords accurately. The linear resolution must be 0.001” with a linear range of 0.001”, and a life span of 10,000 linear inches. It is also desired that each unit be as lightweight as possible, preferably under 80 grams, and cost under $800.

Part #	**Component**	**Quantity**
1	Arduino Nano	1
2	Faulhaber AM1524 Stepper Motor	3
3	TI SN754410 - Motor Driver	3
4	ABS plastic base	1
5	ABS horizontal cord anchor	2
6	ABS vertical cord anchor	1
7	Cord guide	1
8	4-40 all thread rod	3
9	Brass Pinion	3
10	Brass Gear	3
11	Washer	6
12	M2 Set screw	6
13	Visual Demonstration Platform	1
14	Celesco M150 String Potentiometer	2
15	DAQ equipment	1

Table 1 Bill of Materials

Design Changes / Manufacturing Challenges

Upon completion of the initial prototype, it was apparent that some changes in design were need for the unit to perform optimally. The passage that runs longitudinally through the base for the straw adjustment needed to have an access hole to allow for the solution to dissolve the 3D printer support material. Also, resolution of printed parts were quite poor due to low node count of STL file. The number of elements in the mesh was increased in order to have finer resolution. Holes were undersized on the first prototype, which led to a need for slightly oversized holes in the second prototype. Gear pockets were also widened in order to accommodate thrust washers. Provisions for mounting the electronics were added to the lower portion of the mechanism base.

Other manufacturing challenges as mentioned previously, include the machining of the 4-40 all-thread rods from FAMU-FSU College of Engineering machine shop. Due to the small size of the rods, the machine shop's clamps were unable to securely hold them for machining which resulted in the rods popping out during machining and becoming mangled and bent. This issue was resolved by contacting Harris Corporation who had machined similar pieces in the past with great success, and the company was gracious enough to machine these for the team successfully and with great precision.

Although not a huge issue, the gears which were machine by the college, varied in width by ±0.01" which made shimming of the gear somewhat of a necessity to ensure proper gear alignment with the pinions.

Reliability

To prolong the lifespan of the adjustment mechanism prototype, special attention is necessary to observe whether there is any wear to any of the essential components. Hazards to be aware of can be caused by basic functions of the mechanism from any of the moving parts. A few problems will be listed, but the operations manual will go in depth with more problems and solutions on how to solve them. The guide holes for the 4-40 thread may eventually wear away from the piece translating back and forth. This may have to do with the material used for the base of the mechanism. If observed, the base should be replaced, preferably with a stronger ABS plastic material that can withstand more cycles. To avoid wear of the base from the gears, low friction nylon washers were implemented. Over time, if the washers are noticeably degrading, it is recommended that they be replaced. Along with the replacement of the washers, the drive system that consists of the gears, pinions, and threads should be regularly cleaned to ensure that there is no debris that may clog the system, and then lubricated to ensure smooth interaction. Set screws are used to maintain the position of the motors and the pinions to the motor shafts, occasionally they may need to be tightened to ensure consistent results and functionality.

Economics

Since there is a need for over 130 adjustment devices for a single reflector with 7 ribs, keeping the mechanisms cheap and simple is a foremost concern. An example of how this was accomplished, was using a 3D printed main base. When compared to a fully CNC'd piece is much less costly and faster to manufacture. Rather than having a third party manufacture the required gears to the needed specifications, raw gear stock was purchased and machined in house to match the application needs, dramatically reducing cost per unit and avoiding costly re-tooling fees and expenses. Using the Arduino platform was also a cost-saving move, as these units are quite affordable and provide sufficient control functions to run the adjustment mechanism.