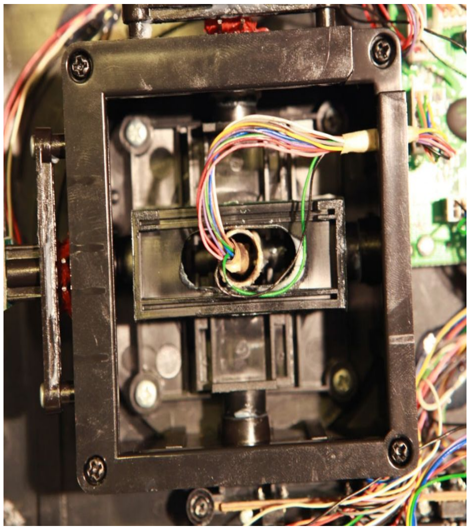

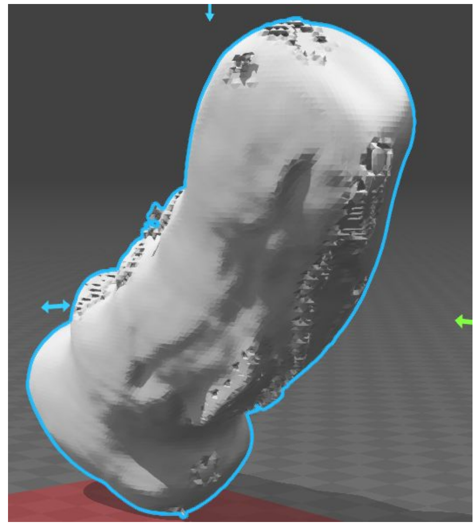

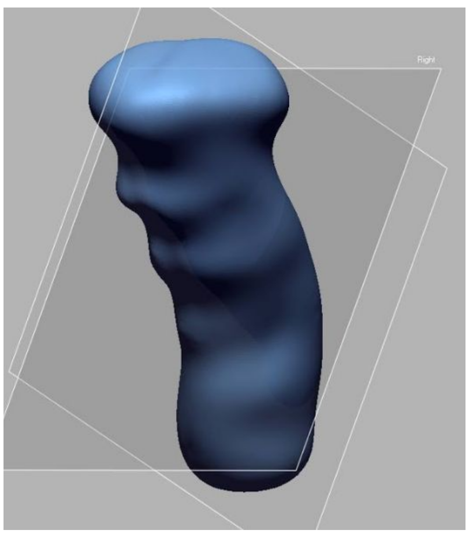

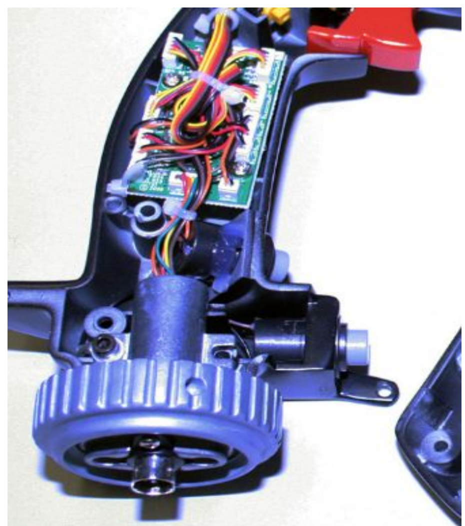

Case Study 3 Report - Group 33

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Introduction

In this case study, we were tasked to design a joystick that would fit accurately to a unique user's hand. This joystick must feature a comfort grip that is also ambidextrous. In other words, it must be easily gripped by a left or a right hand user.

In this designing process, group used Moon Sand to create a mold of the selected volunteer's hand. Then, scanned data were imported as IGES file to NX. Utilizing a Mesh feature, we were able to design a CAD replica of this mold. This latter was sent for rapid prototyping.

In this report, we'll discuss background, features for a good Joystick, CAD rendered Joystick and conclusion.

Background

Joystick is an input device that reports for its angle and direction to the machine it is controlling. It consists of a stick that hinges on a base with supplementary buttons and switches placed on the base and on the stick.

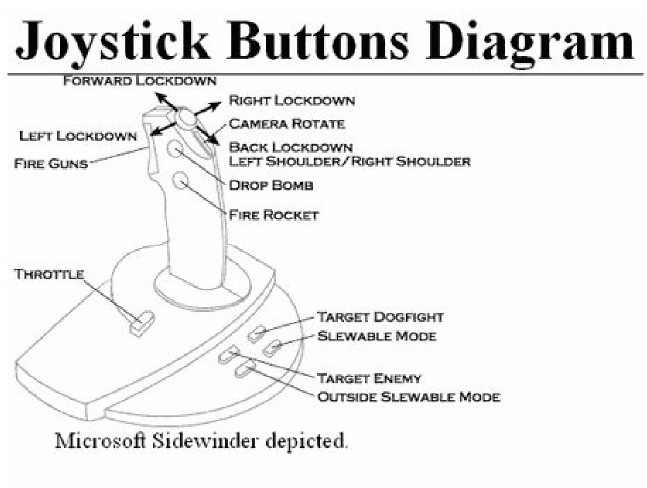

Figure 1: Depicts a gaming Microsoft Sidewinder Joystick

Joysticks are usually exploited as a principle control device in the cockpit of different types of airplanes as either a center stick or a side stick. In addition, this input device is used in gaming industry, in controlling unmanned vehicles, surveillance cameras, cranes and trucks.

The electrical 2 axis joysticks was invented around the end of the 2nd world war era in Germany. Its main task was to aid in aiming a glide bomb Henschel HS 293 against enemies' ships. Missiles were connected by a thin wire to transmit the signal from the input device to the missiles. The joystick was used to steer the missile toward the desired targets. This invention was later upgraded to a device that allowed this electrical signals to be transmitted through radio waves to missiles, hence allowing users to take aim at a longer range targets. This variant of a joystick was created by a team of scientists in Peenemunde.

The first gaming joystick came with the Magnavox Odyssey Console in 1967. This early version of a joystick allowed user to control the horizontal and the vertical position of a spot on a displayed screen. The well-known Atari standard joystick was introduced in 1977. It was specifically developed for Atari 2600, a second generation home video game console. This joystick allowed user a 4-way control plus it featured a designated fire button placed on the base. It also had a DB9 electrical connector.

Figure 2: Shows an Atari 2600 standard Joystick

Later joysticks feature a rotary potentiometer which allow the consoles to indicate the stick displacement from its neutral position without the need for a software to track the stick position or estimate the speed at which the controls are moved.

Market

Industries

Automation Controllers is It is a process operate automatically, also, the creation of technology to observe and control the production of products. For example, CAD: Computer Aided Design, CAM: Computer Aided Manufacturing.

Virtual reality gaming is where person could experience being in 3D environment and react with that environment through the game, hence, that is the main part of the game, such as the oculus rift or HTC vive.

The robot controller is a mix of software and hardware to control and program the robots, whether a single one or many of them, including an industrial robot controller might be designed in such a way as the figure above.

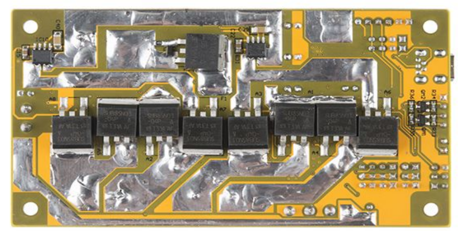

Figure 3: Industrial joystick controller

Sample Market

Star Citizen(a space/flight simulator) generated over 135+ million USD in funding. Virtual reality games like Elite Dangerous, and EVE Online. Star Citizen has a registered 1,700,000 users. Figure 1, depicts monthly revenue of star citizen 2,000,000 to 5,000,000 around USD, moreover. Figure 2 shows daily revenue ranging from 80,000 to 90,000 CAD. This validates the market for potential customers looking for a comprehensive joystick and HOTAS setup.

Figure 4: Crowd funding revenue through Star Citizen

Solution

The design problem requires the need of a universal joystick design, durable material, and easy, cheap/efficient, manufacturing process so we positioned are team to be vertically integrated.

Vertical Integration

Vertical integration dictates that one company controls the end product as well as its component parts rather than the manufacturing and sourcing of materials. In technology, Apple for 35 years has championed a vertical model, which features an integrated hardware and software approach with assembly and distribution outsourced to suppliers and manufacturers. It is about a company having many activities that related to vertical integration.

Structure

Vertical integration can be subdivided into complete integrated or incomplete integration. Forward integration occurs between the two stages of production. However, incomplete integration is a type of integration when it does not achieve the production stages of self-sufficiency of internal. This is in contrast to horizontal integrated companies, including the huge petroleum companies, which owns and unite all production processes, starting from discovering new oil fields and ending of the distribution of the oil, which the company produce it in the supply and distribution its own. However, in some other industries we do not find this integration adequately. In construction operations, horizontally integrated, we can find that there are many separate companies that do different activities and some of them is developing designs and provide raw materials and other construction operations. Also, and even within the same industry we may find that companies are varied and differ significantly with respect to vertical integration.

With our structure the team has decided to design a universal joystick attachment for existing bases and have a custom pull over grip sleeve for a custom fit.

Reverse Engineering

Defined as "the reproduction of another manufacturer's product following detailed examination of its construction or composition." by Wikipedia. In case study 3, the team had to go through a 3D scanning process, repairing the mesh, analysis through NX for stress and primitives. We created molds to retrieve point cloud data and transformed them into mesh data. From mesh data we created solid surfaces for manufacturing.

Figure 5: Mold created for class

3D Scanning and Repair

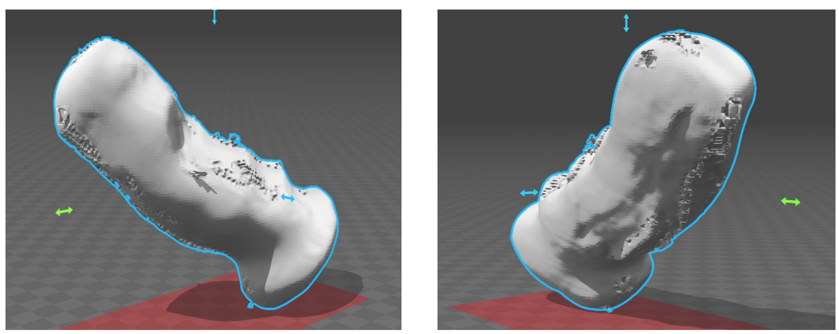

Figure 6: Mesh unedited generated from point cloud data

Initially, the cloud point data had aberrations in the mesh generated by Rhinoceros. To repair the mesh, the mesh was imported into Geomagic Studio X where the abnormalities were filled or smoothed with the available mesh correction tools.

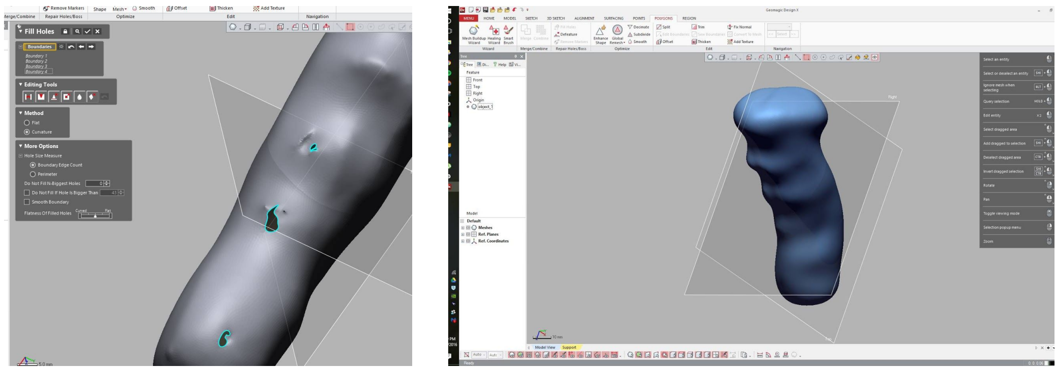

Figure 7: Mesh repair through Geomagic Design X

The meshes were then subdivided into a low poly mesh and a high polymesh, the high poly mesh would be used to 3D print the sleeves and the low poly mesh is required to create an NX solid surface. This is done by extrapolating surface models over the triangles of the STL poly mesh.

Analysis through NX

In NX a surface primitive definition was used to detect the complexity of the sleeve body. The complex nature of this sleeve reveals the difficulty of the injection molding process of mass producing such a part.

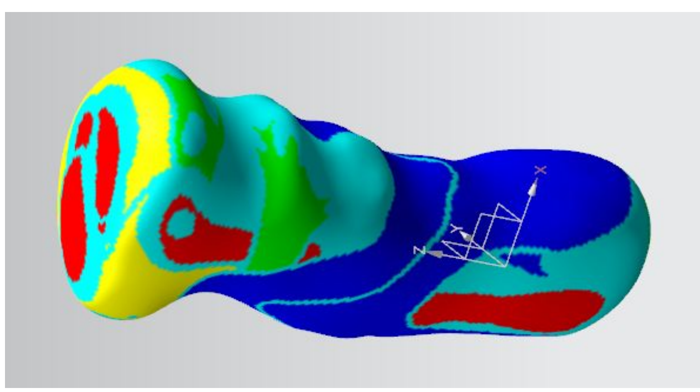

Figure 8: NX used to generate primitives for mesh facet

The team was limited on time to further apply finite element analysis to detect fracturability of the object. Though this would be more useful for determining the durability of the internal cylinder structure.

Rapid Prototyping

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

Joystick Design Deconstruction

In the figures below of an existing Saitek X52 Pro joystick taken apart we found that the analog movements of the joystick were picked up by a hall effect sensor that converts the distance of the sensor and the magnetic field to digital displacement values.

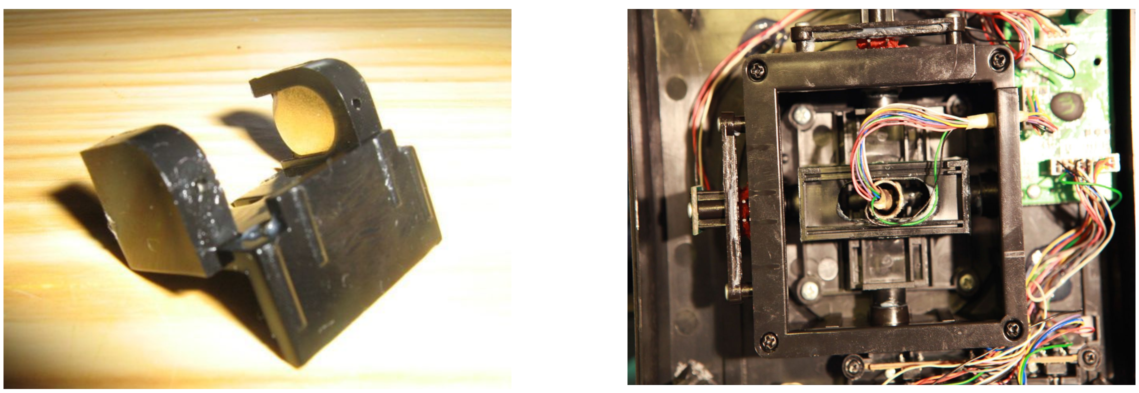

Figure 9: Components of a popular joystick sensory system

The figure below further segregates the parts of the base of the joystick where the PCB placements of specific parts are revealed. Notice the placement of the primary PCB which integrates the connector for the throttle. The trigger switches, pinky switches, and rudder pot are what needs to be integrated in the planned universal stick.

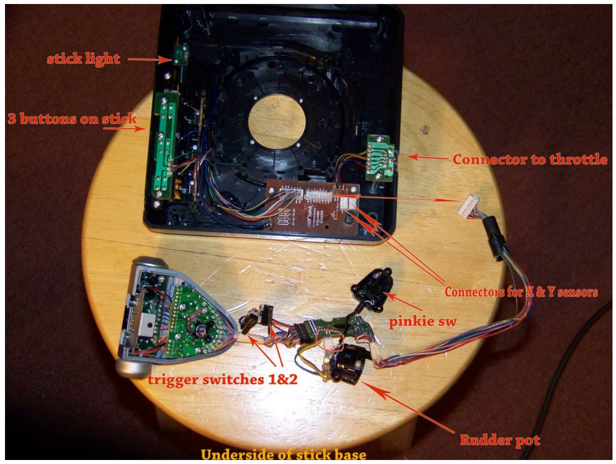

Figure 10: Components of a popular joystick sensory system

User Needs and Requirements

As a flight simulation enthusiast that actively uses a HOTAS (hands on throttle and stick) system, a primary requirement is an interchangeable spring system, see figure below. People vary with physical strength as well as their grip. So the ability to interchange springs of various tensions is necessary in order for accurate control of equipment. The interchangeable spring system also plays into the requirement of being able to change the joystick for custom users.

Figure 11: Joystick interchangeable spring tension system

Manufacturing to Scale - Mechanical Design

Mass production to scale means the initial joystick design is redesigned so that the product can be manufactured in the fastest, cheapest, at quality. Covered are injection molding, design for scale explorations, and die-tooling cost estimation.

Injection Molding

Determining the right method of manufacturing is key to finding the most efficient way to mass produce our design. Since injecting molding can quickly manipulate plastics/polymers our design will be manufactured this way. Injection molding has many benefits including getting a flush shell our joystick design while having key structural supports. The shell of our model will be designed with two different dies which will be the two halves of our joystick. Both molds will be two-plate molds since our model is relatively simple. The mass of existing joystick bases were used.

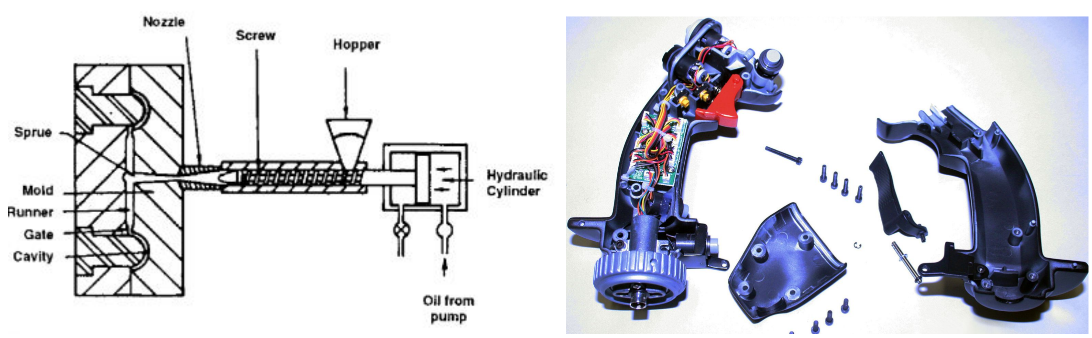

Figure 12: Injection molding apparatus and components of a joystick

To properly manufacture this joystick it is required to know what type of machine is best suited for the job. From calculations the volume of the joystick was found to approximately 249.29 cm^3. This would be if the joystick was completely solid, but it is just a shell to allow for the electronics to fit inside. The newly approximated volume would be 50cm^2, 20% of the original mold. Since this is the case the shot size of the machine would have to be around 76 cm^3 while having a runner of 19%. The machine will need a driving power a bit under 7.5 kW which will give the machine the required clamping force of 500 kN needed to produce our shot size.

Part volume (cm^3)	Shot size (cm^3)	Runner %
16	22	37
32	41	28
64	76	19
128	146	14
256	282	10
512	548	7
1024	1075	5

Clamping force (kN)	Shot size (cc)	Operating cost ($/h)	Dry cycle times (s)	Maximum clamp stroke (cm)	Driving power (kW)
300	34	28	1.7	20	5.5
500	85	30	1.9	23	7.5
800	201	33	3.3	32	18.5
1100	286	36	3.9	37	22.0
1600	286	41	3.6	42	22.0
5000	2290	74	6.1	70	63.0
8500	3636	108	8.6	85	90.0

Next concept in manufacturing is the time required to make one mold which can be separated into three different periods that are injection time, cooling time, and mold reset time. Injection time is how much time the machine required to fill the mold with the required shot size of the joystick. Next is the cooling time because after the material is injected it is still extremely hot and would deform if it is not given enough time to cool within the mold. This is usually the longest period due to many factors including the maximum wall thickness, part injection temperature, thermal diffusivity coefficient of the materials, and actual mold temperature.

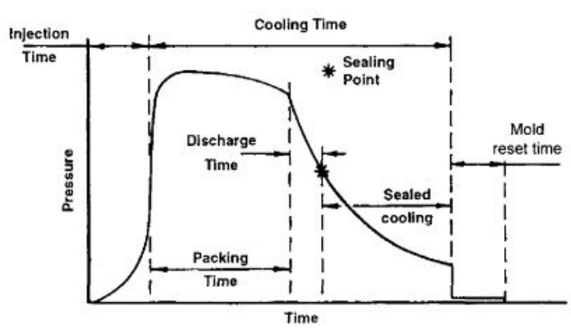

Figure 13: Cure time

Lastly comes the resetting time which consists of the mold opening, part ejection, and mold closing times. These all depend on how complex the joystick is, the more complex the more time it will take to eject the part.

Tool and Die Costs

Calculating the cost required to make the mold comes in two parts, the cost of the prefabricated mold base and the cavity fabrication cost. Estimating the cost beforehand is essential to quality control and feasibility of production to see if the part should be modified in any way before production begins.

Starting with the prefabricated mold base the cost can be estimated to be 1000 + 0.45(15*3)(6)^0.4 = 1042 USD.

$$C_b = 1000 + 0.45\, A_c h_p^{0.4}$$

where
C_b = cost of mold base, \$
A_c = area of mold base cavity plate, cm^2
h_p = combined thickness of cavity and core plates in mold base, cm

The next cost to be calculated is numbers of pins required to eject the joystick. This is simply (15*2.3)^0.5 = 5.87, which will actually be 6 pins in the mold base.

$$N_e = A_p^{0.5}$$

where
N_e = number of ejector pins required
A_p = projected part area, cm^2

The cost of this is calculated by the amount of time it would take to make all the pins, estimated to be 2.5 hours per pin. This leaves us with the cost of 587.2$ if the going rate of manufacturing pins is $40/h.

$$M_e = 2.5 \times A_p^{0.5}\ \mathrm{h}$$

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