Fluid Fill Assurance Vision System

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by

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Problem Statement

Over many years, Toyota Motor Manufacturing has had issues with quality flow outs due to transmissions not having oil present after leaving their manufacturing facility. This results in recalls of vehicles and expensive repairs due to damages caused by the engine running without oil. Their facility has equipment that fills the parts and measures the total volume dispensed. The next process will confirm that oil was filled before letting it advance down the line. The problem occurs when the main equipment is down and there isn't a reliable confirmation method of detecting the oil other than using a dipstick. The dipstick is verified by the team member working on that process to see if there is oil presence. The team member can let the parts pass thru without filling and there is no other detection method to prevent this. Allowing team members to make a determination on a critical process such as fluid fill will result in poor vehicle quality and damage Toyota's reputation for reliability.

Research

Background of the Problem

In a normal running condition, the transmission would go through the oil filling process that has redundant flow meters to measure total volume output. The equipment would fault and stop the line if the volume measured was not within acceptable tolerance. In an abnormal condition, the main oil fill equipment would go down and the team member would manually fill the transmission using a beaker. The parts would then be inspected using a dipstick to verify the oil level before sending it to the next process. The problem usually occurs when a team member forgets to fill the transmission and just picks up the dipstick and sets it down without visual confirmation. The equipment is not set up to ensure the team member looks at the dipstick and confirms. This gives opportunity for process failures. The transmission can either get too low or too high of oil level. All of which attributes to poor vehicle quality and plays a factor in overall engine life cycle. The problem caused by the inefficiency of the oil filling station has cost Toyota manufacturing between $150,000 to $300,000 each year. The cost estimation is an accumulation of vehicle parts, supply materials, and labor cost for repairs.

State of the Art

Conventional level sensors– commonly associated with false readings and unstable detections. Along with these concern, external factors such as, build up, foam, and rust would further amplify these issues with conventional level sensor.

- **Float type**
  This type of monitor is a float that sits on the surface of the surface of the liquid. Since moving parts are required, it is subject to false detection due to breakage or the float become stuck. Often give false detection caused by float becoming stuck, breakage of the float, and bobbles/foam on the surface. Also, not compatible with viscous liquids. (1)

- **Electrode type**
  This type works by measuring the conductivity between electrodes, since it can only detect electrical conductivity. Detection is affected by the environment. The problems with electrode type are false detection caused by coating/rusting and condensation. It is not compatible with non-conductive liquids or viscous liquids. (1)

- **Ultrasonic type**
  This type uses the reflection principle of ultrasonic sound waves. Since sound waves lend to spread, detection is affected by objects inside the tank. The problems with Ultrasonic type are false detection caused by spreading sound waves, ripples, and bubbles/foams on the surface. (1)

End User

This device is specific for Toyota assembly line worker to use daily at the oil inspection station. This device will be used as an eye of the worker to check the appearance of the oil (2). Beside assembly line worker, members of the team TEMA will use the device as oil visual data for their projects.

Summary of Research

The research provided some helpful ideas for the design concept. I have learned much more about different type of sensor and methods of how to use them. After many researches about the sensor and how they work, I came up with an idea that provide a reliability and durability for the project. The idea of this method is based on the ultrasonic sensor and the worker on the assembly line. Instead of having human eyes confirm if there are oil inside the engine, my idea is having technology replace the human eyes to confirm it instead. This method required a high technology camera to detect oil and save it as evidence to prove that there is oil inside the engine and good to move on to the next station. After many discussions, employee and I contact Keyence and meet up them to get information about their camera. After meeting up with Keyence and was able to see the demonstration of their products, I came up with a few more ways to make this project achieve the requirement.

Quality Function Deployment

Customer Features

The customer is looking for a reliable method for oil confirmation. Their core values for any equipment coming into Toyota is Safety, Quality, Productivity, and Cost.

The equipment must meet all Toyota safety standards that based on OSHA safety standard (3) prior to allowing team members to use. Equipment shall go through a review process by core safety and all parties involved to make sure it is safe to operate on. A risk assessment should be done and approved prior to design approval.

The equipment must pass all quality requirements set by the customer:

1) No vehicle parts shall be damaged by the equipment.
2) Equipment must be set up to ensure quality cannot be bypassed without going to a backup method and approved by the team leader.
3) No contaminants should be added to the process.

The equipment must be reliable and durable. Toyota has tried many different types of oil assurance methods and the biggest challenge is reliability. If the equipment keeps getting false readings, this will have a big impact to production rates. It must be able to keep up with current operating rate of one vehicle per 55seconds. New equipment must not take longer than 10 seconds to confirm oil presence. The parts need to be durable since this is a manufacturing environment. Team members can be very rough on the equipment when they are in a hurry. A 3000 cycle endurance run needs to be done prior to handover.

Cost is always a key factor in deciding what type of confirmation equipment is needed. Currently the goal is to keep the equipment under $10,000. Keeping the equipment as simple as possible without compromising the core values is key.

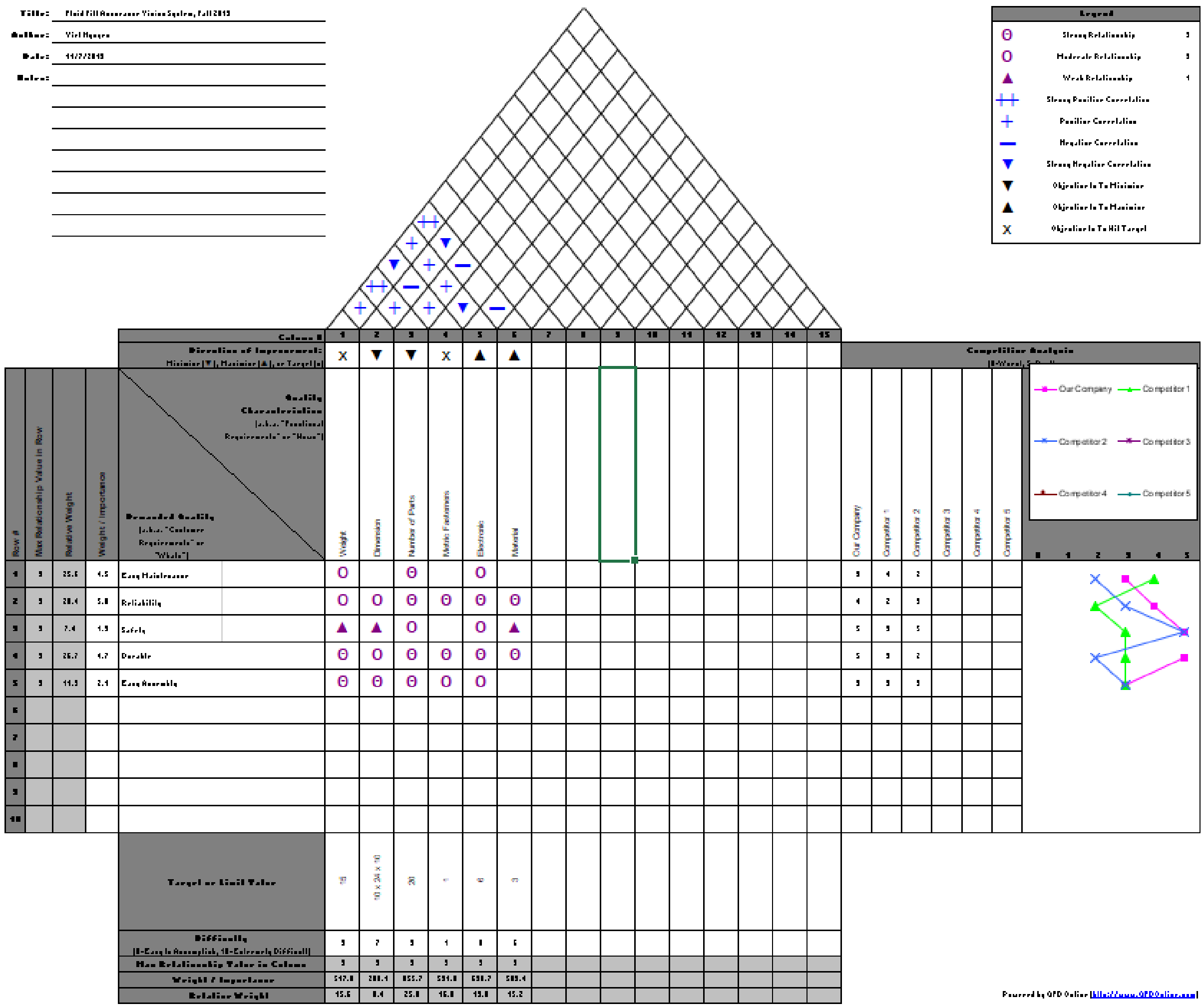
Engineering Characteristics

Weight	**Metric**
Dimension	**Minimize**
Number of Parts	**Minimize**
Metric Fasteners	**Metric**
Electronic	**Maximize**
Material	**Maximize**

- **Weight**
    - Utilize the material property
    - Utilize the dimension property
- **Dimension**
    - Use metric measure

    - Proper diameter for the workplace
- **Number of Parts**
    - Minimize the number of parts
    - Combine many sections as possible to reduce the number of parts
- **Metric Fasteners**
    - Use metric fasteners
- **Electronic**
    - Research and find the best device that fit for this project
- **Material**
    - Use the material that are provided in school and the company
    - Special request for a specific material if needed

House of Quality



Product Objectives

- Easy Maintenance (25.6%)
    - Low cost
    - Ease repair
- Reliability (28.4%)
    - Long term
    - No error or misread
- Safety (7.4%)
    - No biohazard that reach employee
- Durable (26.7%)
    - Survive harsh environment
    - Able to operate 1,500 cycle a day
- Easy Assembly (11.9%)
    - Metric bolts and dimension

To ensure all objectives are met, I will meet regularly with the customer to discuss design concept and any changes that occurs. I will use the Toyota core values as a guideline to determine what is the best solution.

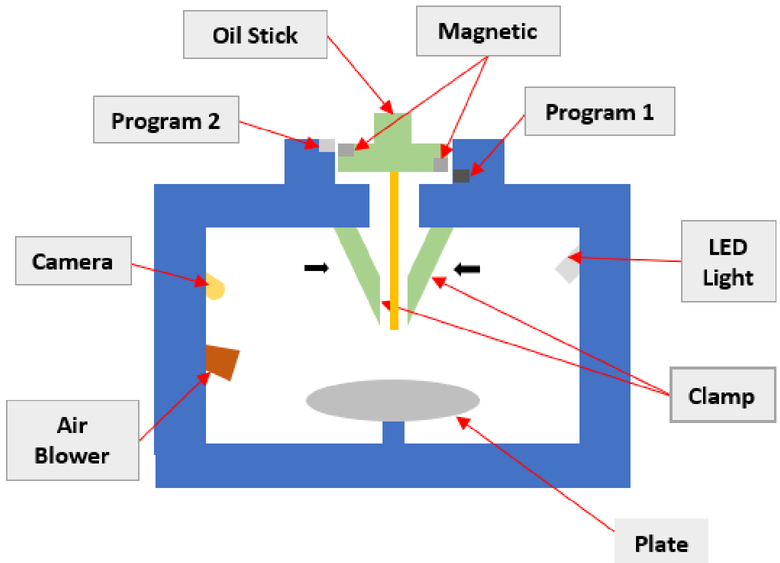
The equipment will use the Toyota safety guidelines to ensure all safety requirements are met. I will utilize light weight components and low power devices when possible to reduce the safety risks.

Equipment material will consider the use of nylon and other softer materials to prevent from damaging the transmission or rear differential aluminum housing.

The equipment will not introduce any additional contamination to the oil that isn't already there at the current process.

All parts to be used on the new equipment will consider durability of each component before incorporating into final design. Parts will be put through an abnormality check to ensure it does not get damage in unforeseen circumstances. I will utilize material and parts that are already being used at Toyota and has proven to be reliable.

Concepts Drawings



Design Concept 1

Operation

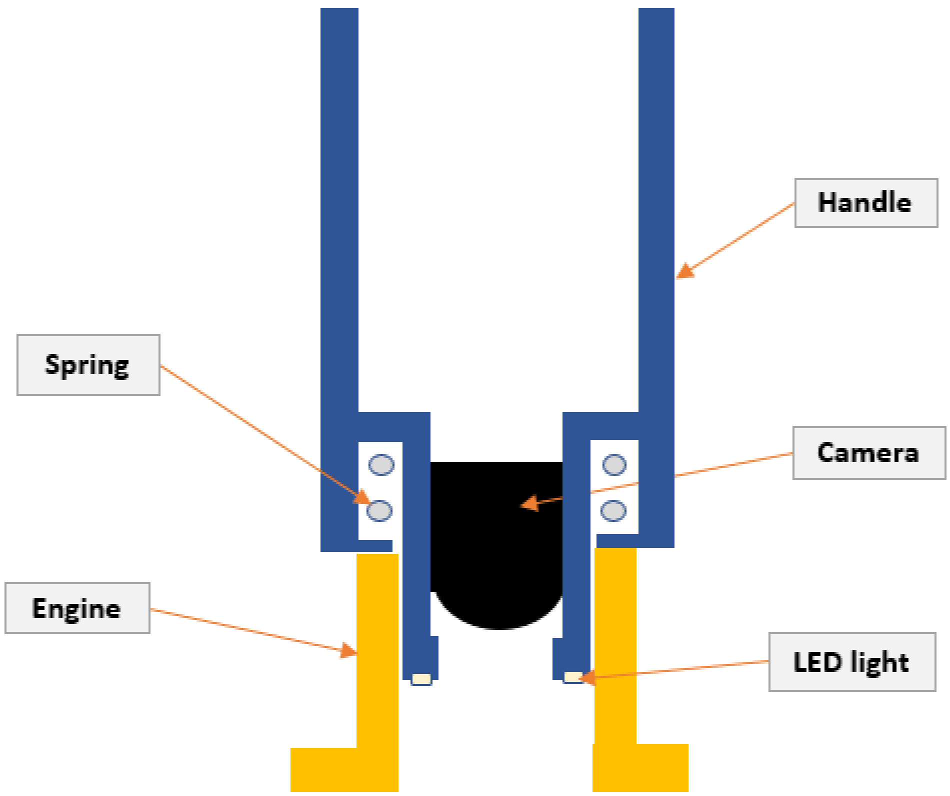
Step 1: Insert the oil stick into the engine.

Step 2: Remove the oil stick from the engine, then insert the oil stick into the assurance Vision System.

Step 3: Remove the oil stick from the oil check device.

Description:

When the operator inserts the oil stick into the oil check device, the magnetic key will activate program 1. The clamp will clamp into the oil stick. After the operator remove the oil stick, the magnetic will active program 2. When the program 2 is activated, the LED light will turn on, camera will take picture, and then the air blower will blow the oil off the plate. the device will go to rest mode after. There will be another program that will give signal if there are oil visual in the picture.



Design Concept 2

Operation:

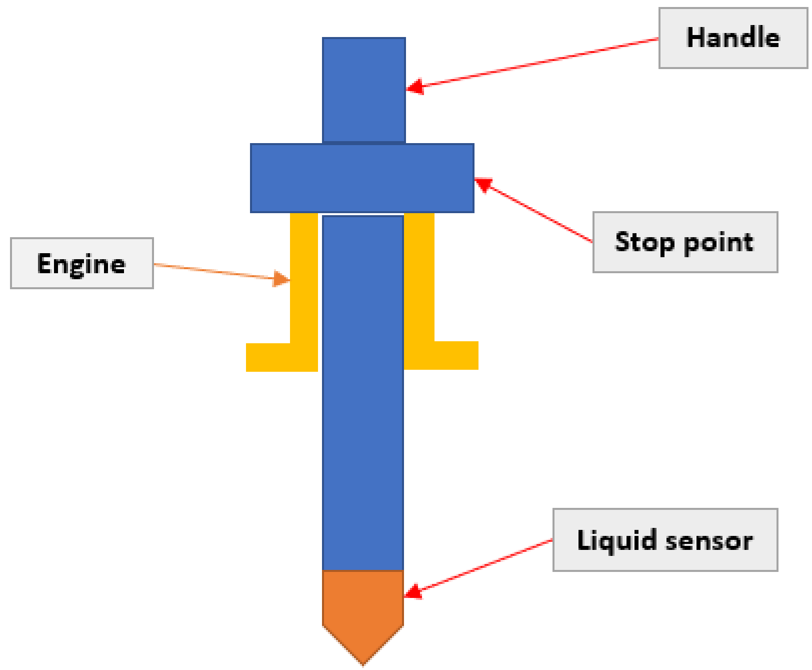
Step 1: Insert the camera inside the engine.

Step 2: Press down the camera handle. Wait for the LED light to turn on and the camera to take picture.

Step 3: Remove the camera from the engine.

Description:

When the operator presses down the handle, there will be 2 clicks sound that respond to the operator down force to the handle. The first click will turn on the LED lights that are set on the bottom of the handle. The purpose of the light is to shine light inside the engine for the camera to take a picture. The second click will command the camera to take a picture and send to another program that will analyze the picture and give out signal if the oil is visible. When the operator removes the device from the engine, the light will turn itself off.



Design Concept 3

Operation:

Step 1: Insert the device the inside the engine

Step 2: wait till the liquid sensor send feed back

Step 3: remove the device and wipe the left over oil

Description:

The handle will be attached with a liquid sensor with a program that will give signal when the edge of the sensor interacts with oil. The handle will also attach with adjustable stop point to change the length of the sensor. Possibly can be use to measure the amount of oil inside the engine with the adjustable. When the operator inserts the device inside the engine, the liquid sensor will make a contact with the oil and give feedback to the receiver if there are any oil. Once the oil is detected, a program inside the receiver will capture the data and save it.

Project Management

Project Budget Limit

Cost will be kept to under $10,000 by utilizing local resources to make prototype design. I will work with the Toyota Tilt Lab and UC's lab to make and test the parts. I will work with the customer to see if they can provide certain components that are already available at Toyota. Equipment simplicity will be the ultimate goal for keeping cost down. The table below is the estimate for the parts and cost

Part	Cost
Frame	$100
Electronic devices	$8000
Material	$200
Miscellaneous	$1000
Total	$9,300

Key Milestones

Milestone	Estimated Date
Design Agreement	10/11/2019
1st Sub-model Iteration	11/11/2019
Testing Method	12/20/2019
Development/Improvement	1/10/2020
Complete CAD Model	1/21/2020
Test Prototype	2/28/2020
Presentation	4/17/2020

References:

1. Sensing Guide Pulse Level Sensor.

Sensing Guide Pulse Level Sensor - FL series | KEYENCE America [online]. Available from: https://www.keyence.com/products/process/level/fl/index.jsp?search_sl=1

2. Department of Labor logo UNITED STATESDEPARTMENT OF LABOR.

1910.22 - General requirements. | Occupational Safety and Health Administration [online]. Available from: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.22

3. Department of Labor logo UNITED STATESDEPARTMENT OF LABOR.

1910.106 - Flammable liquids. | Occupational Safety and Health Administration [online]. Available from: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.106

Appendices

Design Process

The meeting with the employee were scheduled every month to updates and changes the designing process. There were times when the meeting was cancelled due to company and student busy schedule. Many details were added and changed due to the features that the company see it fit for their assembly line. The timeline below is the date of the meeting and discussion.

May 2nd, 2019

- The company approved to sponsor for the project and start to send out details of the requirement
- Requirements
    - Durable
    - 250,000 cycles a year

May 17th, 2019

- Discussion about design concepts
- Talked about the project that were tested in the past and why it failed
    - Ultra-sonic
        - Not reliable due to spreading sound waves, ripples, and bubbles/foams on the surface.
    - Weight scale
        - Not durable due to 250,000 cycles
        - constant under maintenance
    - Air pressure
        - Interact with the oil
        - Contaminated the oil
        - Not reliable (sometimes it picks up the reading and sometime don't)

July 12th, 2019

- Discussion about budget
    - $10,000
- Discussion about requirement
    - A program that can be saved as data to prove that there are oils inside engines
- Take a Break due to Company's busy schedule

September 13th, 2019

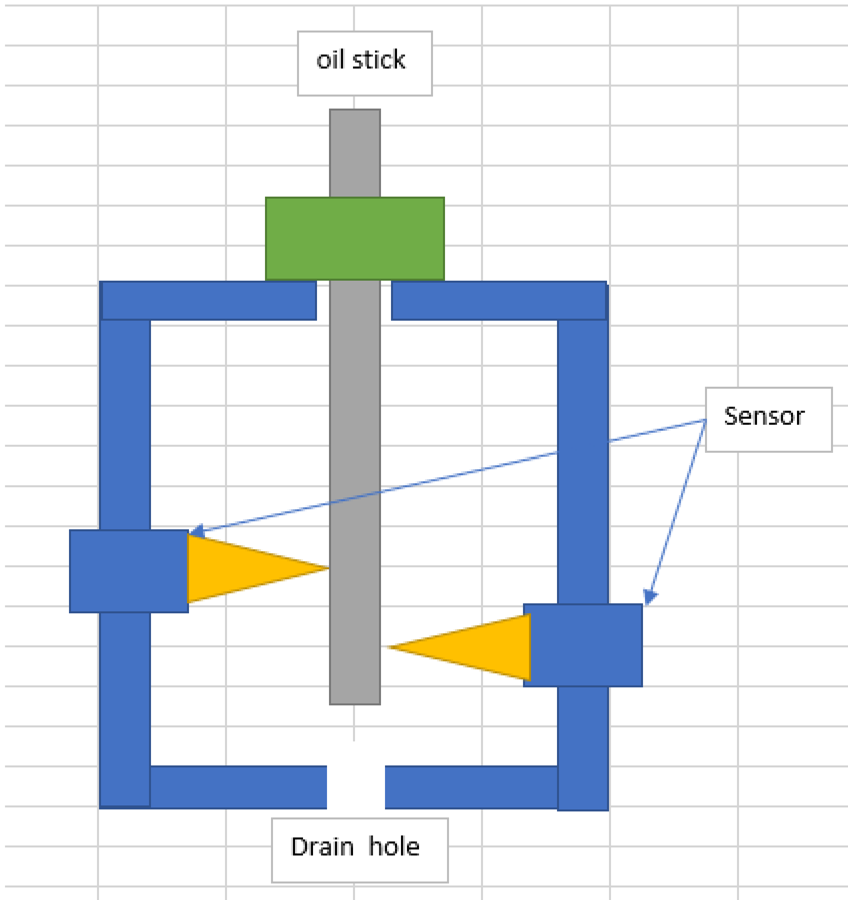
- Discussed about challenge
    - No oil interaction
    - Quick time reading (under 10 second)
    - Easy maintenance

October 1st, 2019 – February 14th, 2020

- Bi-weekly discussion with Employee

- Think new ideas
- Discussed about the failure tested that been done for this project
- Research different material for steel and plastic
- Research different type of sensor and camera

Final Design



Operation

Step 1: Insert the oil stick into the engine.

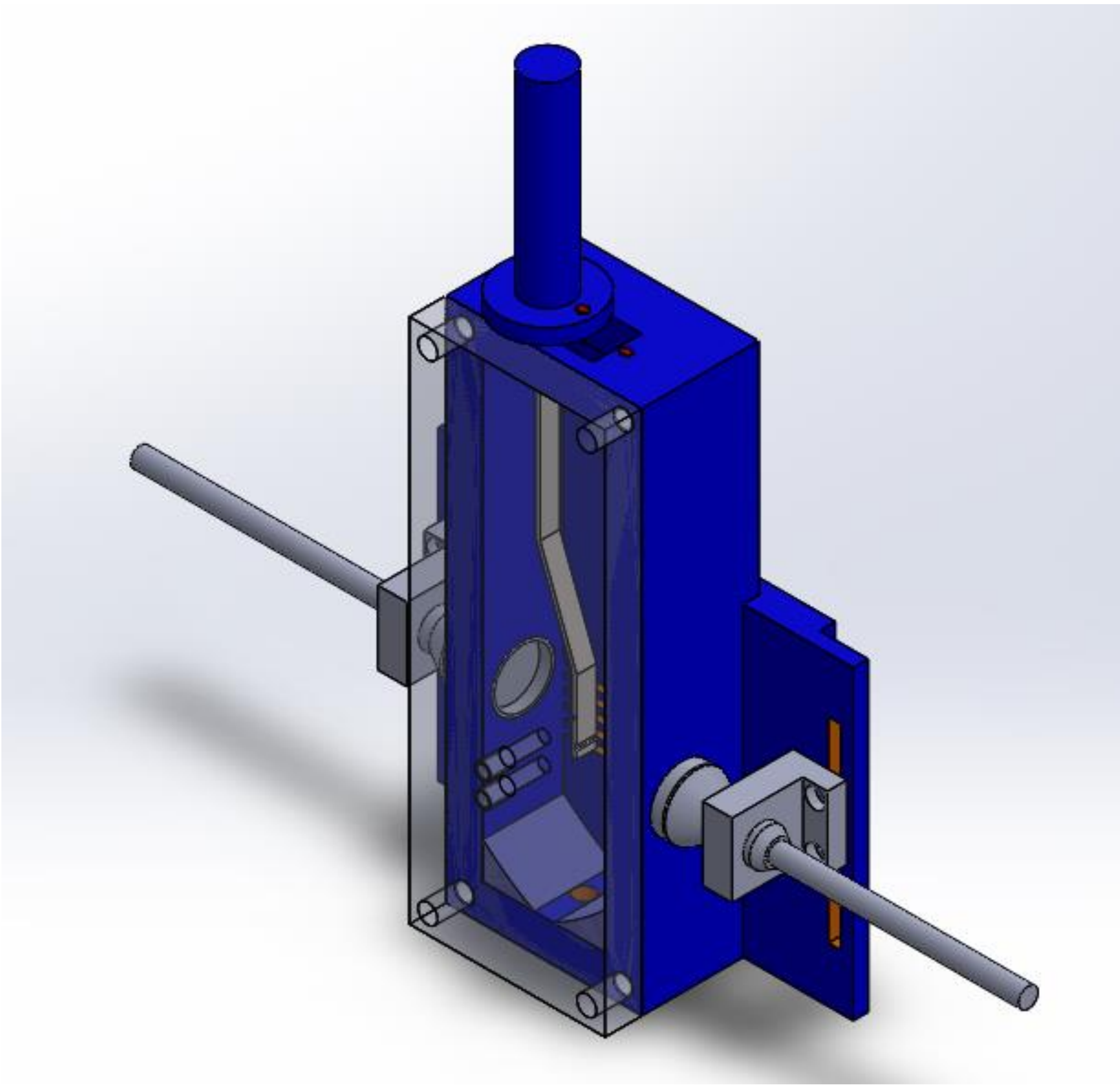
Step 2: wait for the sensor to show the oil thickness and the air compressor to blow the oil off the oil stick

Step 3: Remove the oil stick from the oil check device.

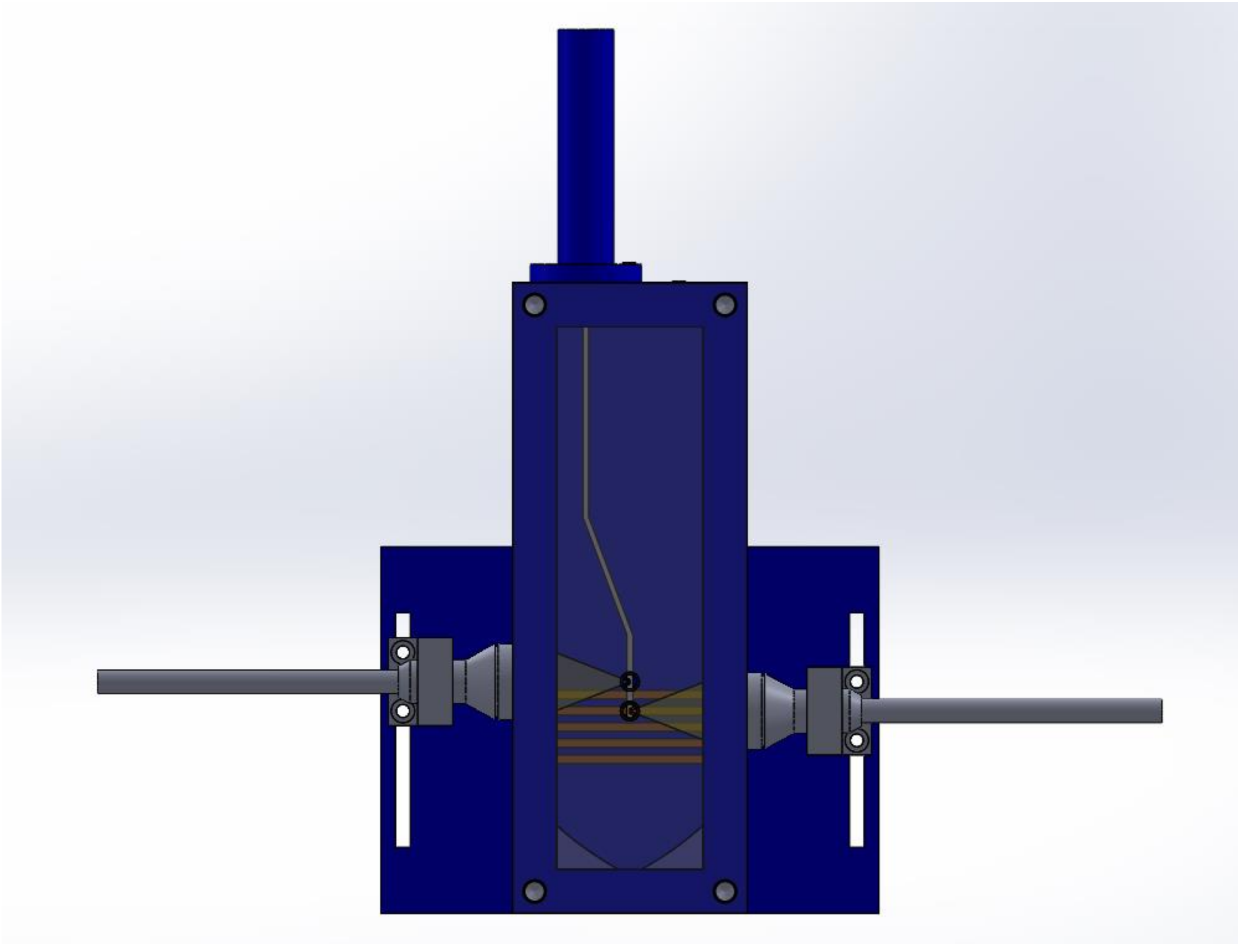
Description:

When the operator inserts the oil stick into the device, the high-precision measurement will measure the thickness of the oil on the oil stick. Then the operator will record the graph from a software that monitor the sensor. if there is a wavelength, that mean there is oil and it also show the oil thickness. If there is no wavelength, that mean there is no oil.

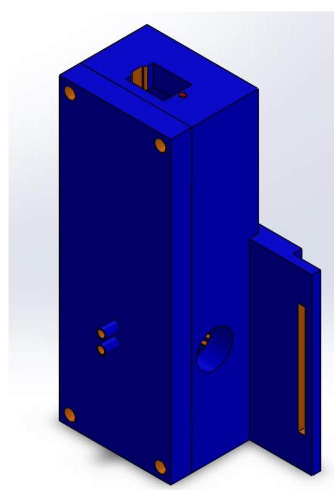
CAD Models



Front view without cover



<u>Frame</u>



Dimension: 80mm x 63mm x 215mm

Material: Blue Nylon

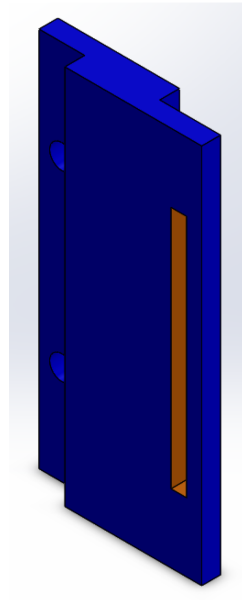
Pre-cut hole for sensor

Extruded tube for air compressor

Arrows for guiding the oil stick face direction

Pre-cut rectangle slot to help center the oil stick

Sensor supporter



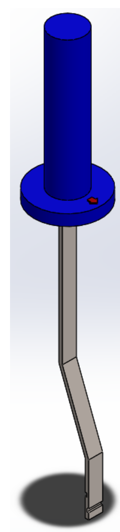
Diameter: 60mm x 12.7mm x 125mm

Material: Blue Nylon

Pre-cut slot to mount the sensor fixture

Slot: 5mm x 60mm

Oil stick



Length: 236.35mm

Material

Oil stick: stainless steel 316 sheet

Length: 150mm

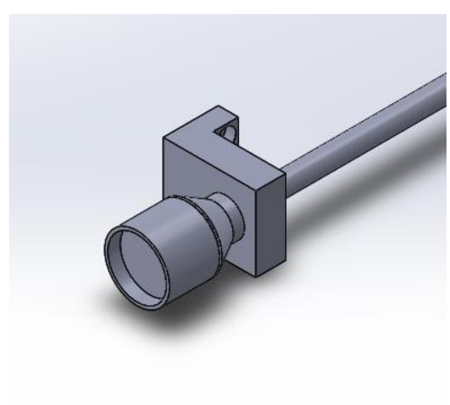
Handle: Blue Nylon

Length 86.35mm

Weight: 53.49g (0.11lb)

Pre-cut rectangle to contain the oil

Sensor



Company: Keyence

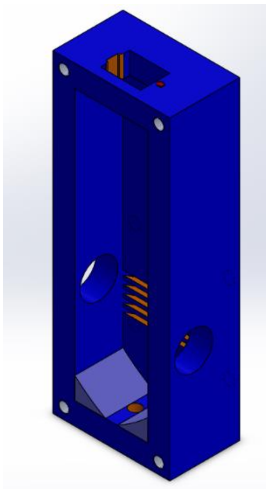
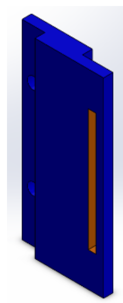
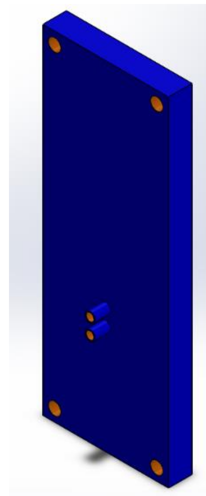
Product: High-precision measurement sensor

Product #: CL-L030

Bill of material

List Part	Description	Price	Model
Keyence	High-precision measurement sensor	$4000	CL-L030
Frame	Blue Nylon	$100	
Customize Oil Stick	Stainless steel 320	$50	
Miscellaneous	Testing material, supply	$50	

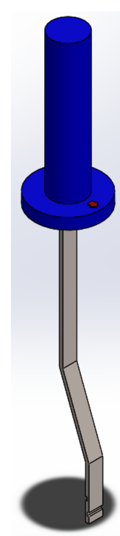
Proposed Fabrication

Frame, cover, and sensor supporter

- Use CNC machine with 3-axis cutting edge to cutout the form of the part and drill hole.
- Use drill press machine with tap head to create thread in the hole.

Oil stick



- Use CNC machine with 3-axis cutting edge to cutout the form of the handle
- Use the rod bender to bend the stainless steel 316
    - Require: rod bender, stationary vise, and angle ruler

Assembly Methods

This project will be assembling with mechanical assembly method by using bolts and nuts. The key of this design is to keep everything simple for ease maintenance. Majority of the material for this project is blue nylon. It is light, durable, and easy to assemble.

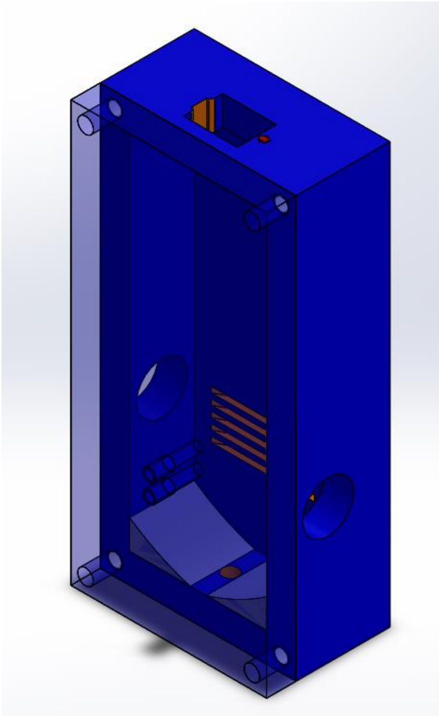


Figure 1: Frame

As showed in figure 1, the frame contained 2 part, the base and the cover. The frame assembly only require 4 bolts of m8 x 30mm.

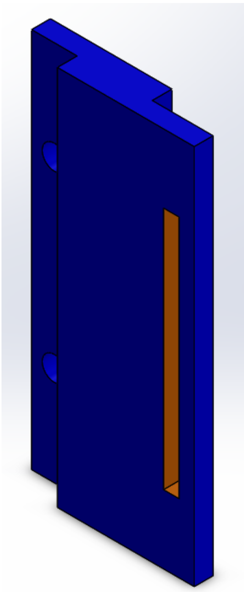


Figure 2: Sensor supporter

Figure 3: Fixture

Before assembling the frame components, the sensor supporter must assemble first with 2 bolts of m8 x 30mm. This will allow the fixture to mount to the sensor supporter and ready to install the sensor.

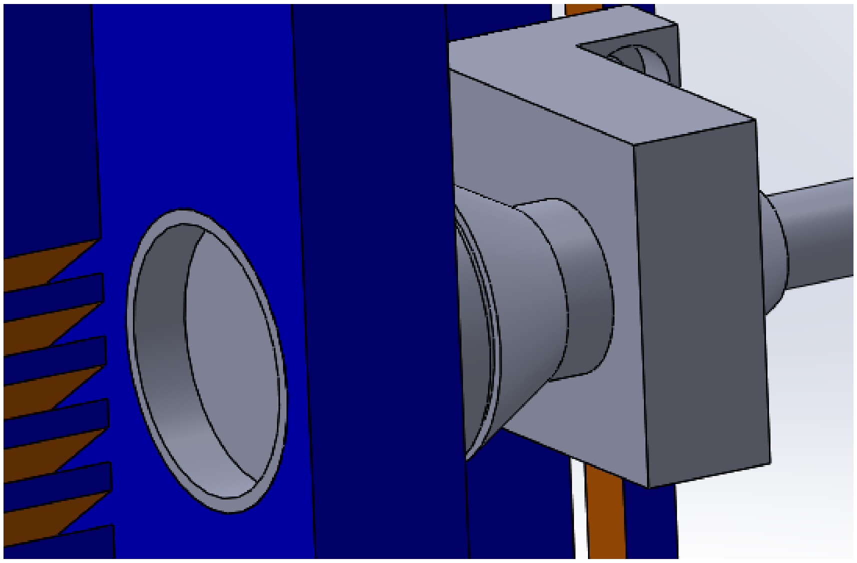


Figure 5: Sensor

The frame designed with a measurement that keep the sensor a distance of 30mm from the oil stick. As showed in figure 5, the sensor head keep flat with the frame surface as measurement distance to the oil stick. After assembling sensor and secure with fixture, test the sensor distance to be 30mm away from the oil stick, then assemble the cover (the layout for assembly the sensor system is showed in figure 7) .

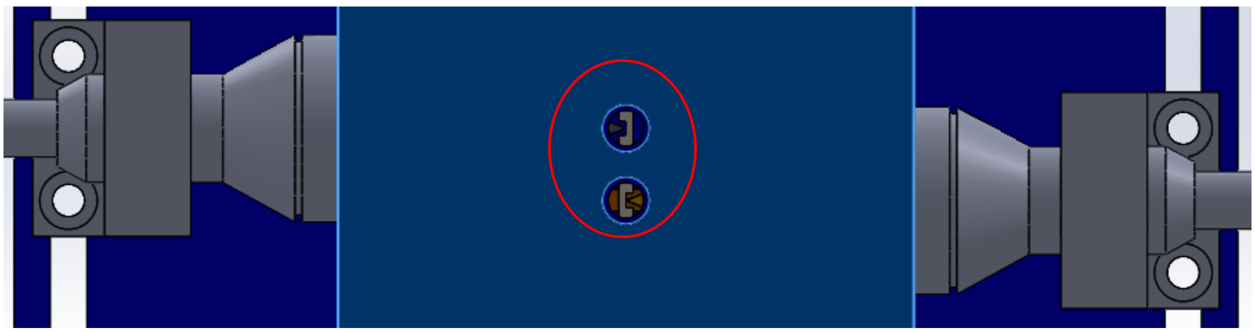


Figure 6: air compressor plug

The air compressor plug designed following the tube manufacturing standard. The outer diameter of the plug is 6mm.

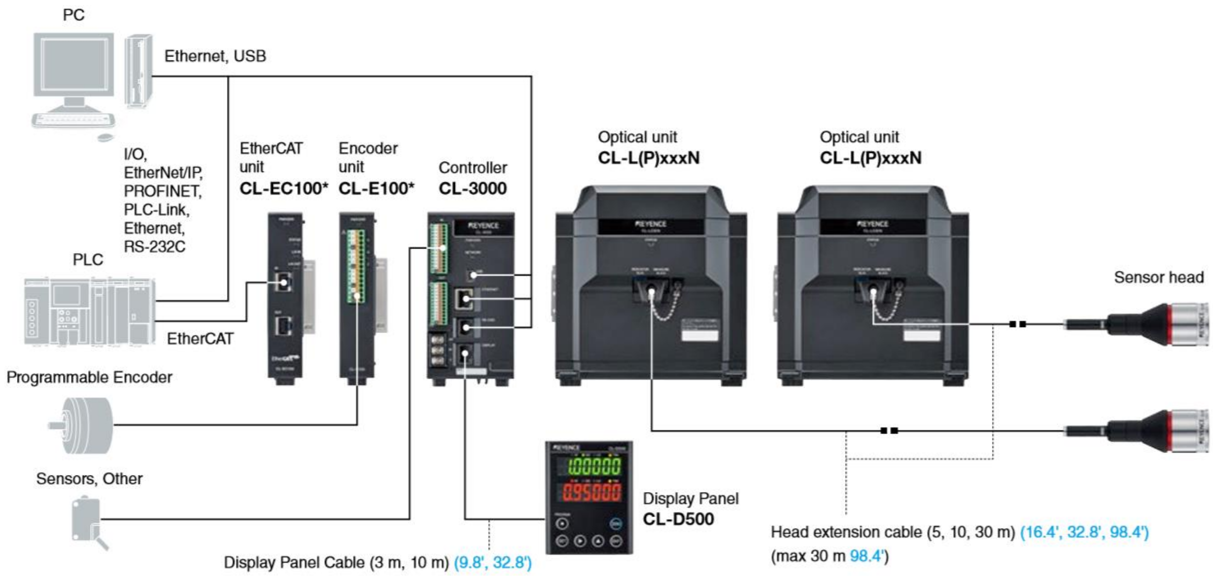


Figure 7: Sensor system

The assembly for the sensor system is followed above. Every part of the system is connected with their own connection system and secured with 2 bolts in each component.

Updated Schedule

Design Concepts	10/11/2019
Development/Improvement	1/23/2020
Testing Methods	1/26/2020
Finalize Method	2/2/2020
Complete CAD Model	2/7/2020
Finish Model	3/3/2020
Test Prototype	3/5/2020
Presentation	4/18/2020

Updated Budgets

Part	**Cost**
Frame	$100
Electronic devices	$4,000
Material	$50
Miscellaneous	$50
Total	$4,200