3D-Printable Faucet Actuator Design Report

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Instructables 2016 3D printing Contest

The Design of the faucet lift mechanism and temperature controlling mechanism is reported here. The statics calculations are depicted for the lever assembly for the flow control half of the devise. The Preliminary and final design for each gear box is outlined along with corresponding motor data for the 1100Kv brushless motors. Finally, the Planetary gearbox design is outlined with appropriate equations and solutions to the drive trains gearing ratio. Manufacturing and assembly processes can be found at this site.

I. Introduction

THis mechanism has been designed, manufactured, and assembled for entry into the Instructables 2016 3D printing contest. It was inspired for the need of a touch-less faucet without buying a motion controlled sink which can cost in the range of $100-500, not including the cost of installation. This design is it is 100% 3D printable, excluding the electronics; allowing someone with access to a 3D printer to build and install one at an extremely low cost.

This report will be organized as follows. First, a general mock-up and of the mechanism will be defined with the constraints such as size restrictions, adaptability, forces and loads that must be achieved, and finally, timing restrictions on flow allowance. Next, the lever arm designs are shown along with the calculations leading to motor selection and the minimum required output torque for a safety factor of 4. Next, the motor specifications will be defined along with the code to produce motor curves for the 10G motor to be used and the preliminary gearbox to produce the appropriate torque. This preliminary gearbox was mostly an experiment to prove or disprove the ability to 3D print ABS high-speed spur gears. Finally, the process of designing the planetary gearboxes will be discussed.

II. Mechanism Constraints

Sensing Ability Requirements:

In order to be a successful mechanism to allow the operator to control it, the device must have four sensors. These include two potentiometers, one IR distance finder, and a pushbutton for calibration reasons. The devise will be activated when the operator waves their hand to one side or the other, in front of the sink with this device attached. The IR sensor will turn on the flow and activate the temperature according to which way their hand moves. Simply leaving the sink will turn it completely off when the IR distance finder reads a distance out of range of a normal standing distance from the sink. The potentiometers can be used on the ends of each gearbox and replace the original time-driven motor controls if high accuracy is needed for potentially sensitive sink controls.

Force Requirements:

Action	Load (N)
Pushing Sideways on Temp. Control	5
Initializing Flow	3
Adjusting Flow	3
Terminating Flow	4

Table 1: Required Load per Action

Basic Layout for Lifting/Pushing Mech.:

Figure 2 below displays the basic geometry to be analyzed in the statics force section. This is also a demonstration of the main actuating mechanism in the design and how it utilizes the faucets flow control to turn on and off the flow of water. The time it takes for normal operation of turning the flow on should be the goal of this mechanism to function which is on average 2.0 seconds to turn the flow all the way on.

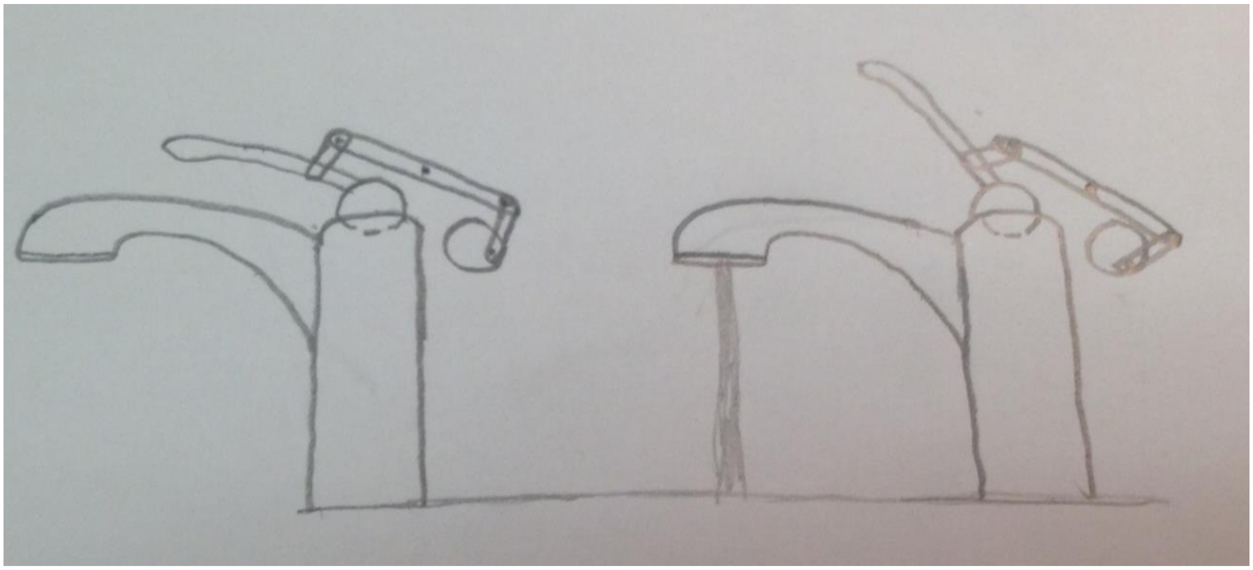

Figure 1: Lever Arm Mechanism Demonstration

III. Mechanism Statics

Sizing on the countertop and sink allow for a lever arm length of 0.186m with the pivot point 0.125m from the handle grip of the sink, a degree of freedom of 23.6 deg, and a spin wheel diameter of only 0.0254m. Knowing this and that the maximum force is at the points of turning off and on the sink, 3N and 4N respectfully equates to a required torque of 0.2081NM and 0.6248NM respectively. Using a safety factor of 3 on the required forces, shows that a max Torque of 0.6248NM must be applied to the spin wheel.

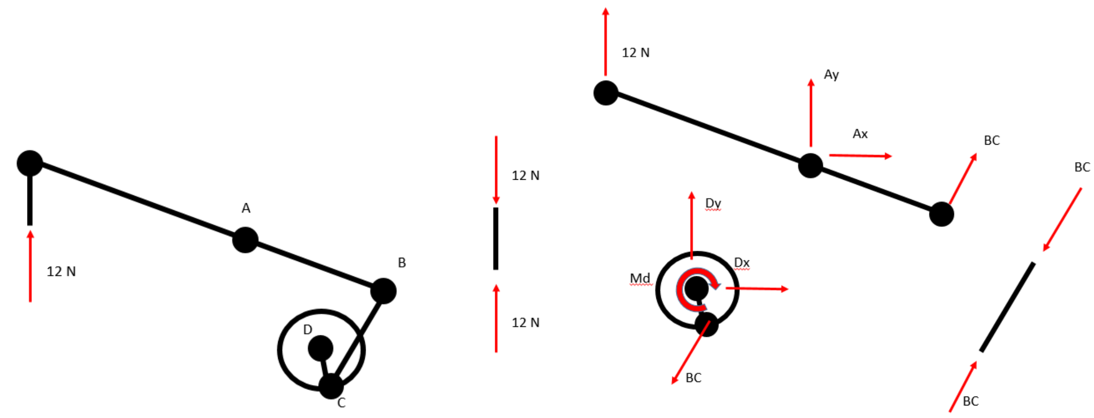

Figure 2: Free-Body-Diagram of Lever Arm Mechanism

$$\sum_{n=1}^{\infty} Ma = 0$$

12N*Sin(52.0)*(0.125M)=BC(0.61m)

BC=19.38N

$$\sum_{n=1}^{\infty} Md = 0$$

Md-0.025*(19.38)*Sin(25.0)=0

Md=0.2080NM

IV. Motor Specifications

Brushless Motor Specs.:

This motor is reliable and at a low cost so it has been selected for use in both horizontal and vertical gear boxes.

<u>1100Kv G10 Brushless Out Runner Specifications:</u>

- Max Current: 32A
- No Load Current: 10V/2.1A
- Power: 355W
- ωfree @ 11V = 12,200 rpm

<u>Electronic Speed Control Specifications:</u>

- Max Current: 45A

Torque, Amperage, angular velocity, and power output equations are listed below along with the Matlab code implementation of them. This is to determine the output speed, amps being drawn, and power output at a safety factor of 2, in order to see if the motor does fulfill the requirements and at what efficiency. Looking at the motor curves, Torque at 16 amps, half of the max rating of the motor, a motor ration of 5:1 is the absolute minimum that is needed to produce the appropriate torque.

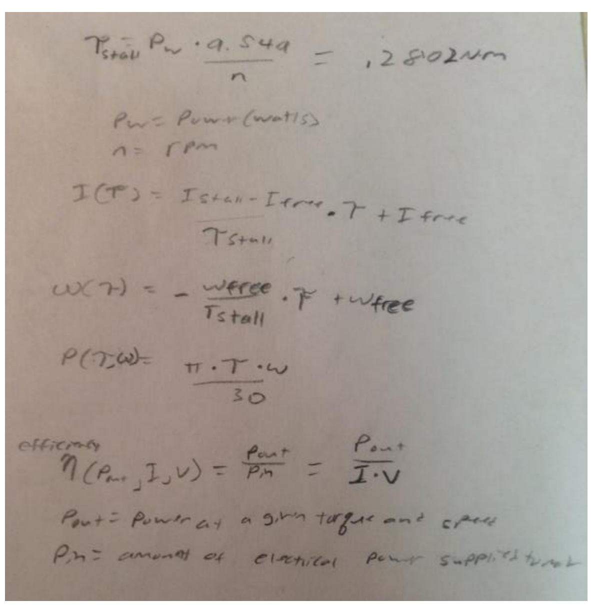

Figure 3: Motor Curve Equations

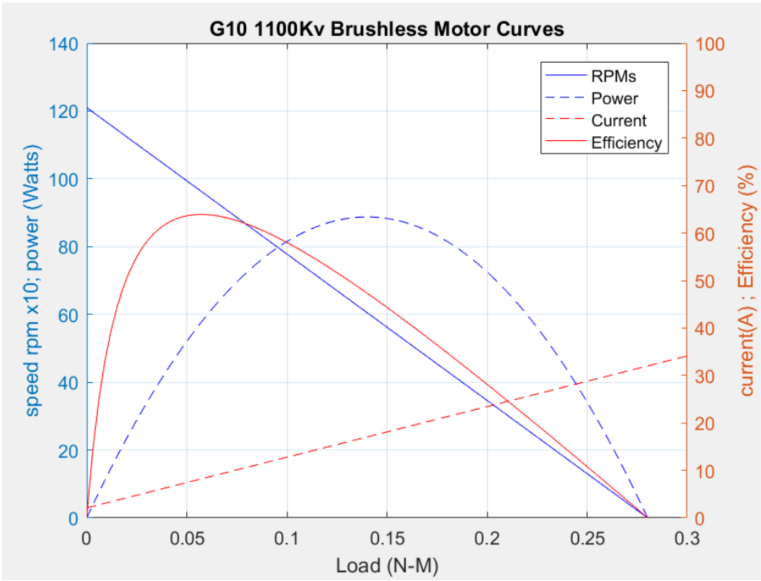

Figure 4: G10 1100Kv Brushless Motor Curves

```
%created on 12/22/2016 by Sam Byrne
%edited:N/A

% the purpose of this code is to plot motor curves for a g10 1100Kv brushless
% outrunner so a gear box may be derived.

clear               % Clears unwanted variables
clc                 % Clears command window
format compact      % Condenses command window for easier reading
%load position_data.txt            % Loads data file Y=position_data(:,6);

Voltage=11;
RPM_const=1100;
I_free=2.1; %amps
Pwr=355;    %watts
RPM_free=Voltage*RPM_const; %12100rpm at 11 volts
T_stall=.2802;
I_stall=32;

%axis definition:
T=[0:.003:.3];

%functions:
I=(I_stall-I_free)/T_stall.*T+I_free;
W=(-RPM_free/T_stall*T+RPM_free);
P=3.1415*(T.*W)/30;
mue=P./(I*Voltage)*100;
W=(-RPM_free/T_stall*T+RPM_free)/100; %graphs with a factor of 10 but needs to be used without in calculations
above

figure
title('G10 1100Kv Brushless Motor Curves');
xlabel('Load (N-M)');            % add axis labels and plot title
ylabel('speed rpm x10; power (Watts)');

%plotting Current:
yyaxis right
plot(T,I,'r--')
axis([0 .3 0 100])
ylabel('current(A) ; Efficiency (%)');
hold on
%plotting efficiency:
plot(T,mue,'r')
grid on

%plotting Speed:
hold on
```

```
yyaxis left
plot(T,W,'b')
axis([0 .3 0 140])

hold on
%plotting power:
plot(T,P,'b--')

legend('RPMs','Power','Current','Efficiency')
```

Figure 5: Matlab Code for Motor Curves

<u>Motor Specification Results:</u>

Max current: 32 A

Saftey factor: 2

Torque at 16 A:

(16-2.1)/(32-2.1)*0.2802 = T(16) = .1303N-M

Motor Ratio:

0.62484N-M/0.1303 = 4.795 = 5:1

Efficiency: 50%

ωmotor = 0.50*(-ωfree/Tstall*T+ωfree) = 32,365 rpm

Disk D (spin wheel) should spin at 32,364/5 rpm = 6,473

V. Preliminary Gearbox Design

<u>Gearbox Specifications:</u>

- Ratio: 5:1
- Service factor: moderate shock
- Moderate Shock Constant: 1.25*0.85 for 3hr/day
- Basic size = nominal torque*service factor = 0.62484*1.25*0.85 = 0.6639
- Stage # (Reduction): Double reduction 3/1 5/3
- Estimating Center distance for first reduction half:
    - Tout = 30*P/(pi*ω)*Gear Ratio*Service Factor=30*90W/(pi*32,365)*3/1*1.25*0.85 = 0.085 N-M
    - Roughly 50 mm Distance

Output Torque vs. Center Distance

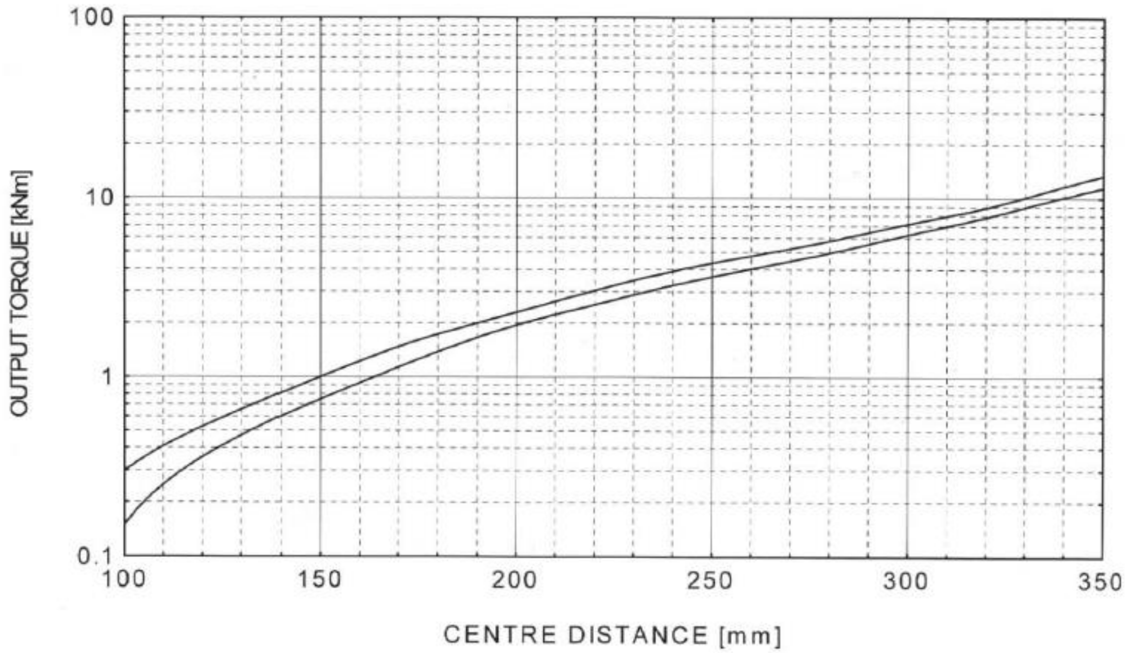

Figure 6: Output Torque vs. Center Distance (borrowed from Technical University of LODZ)

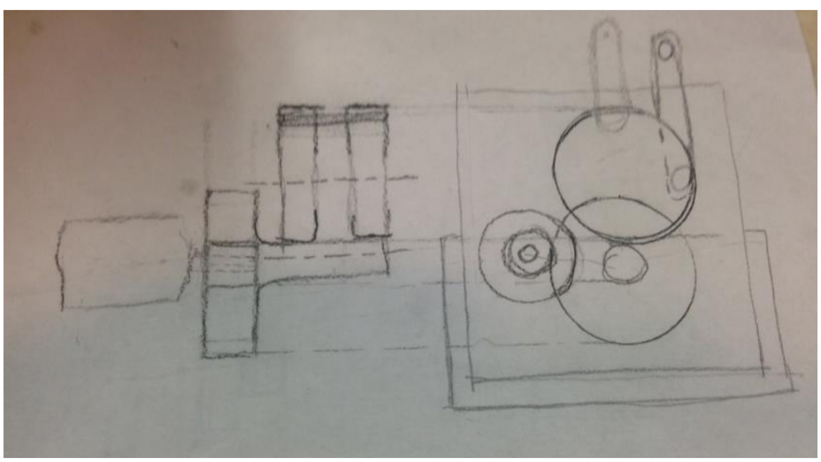

Figure 7: Preliminary Gearbox

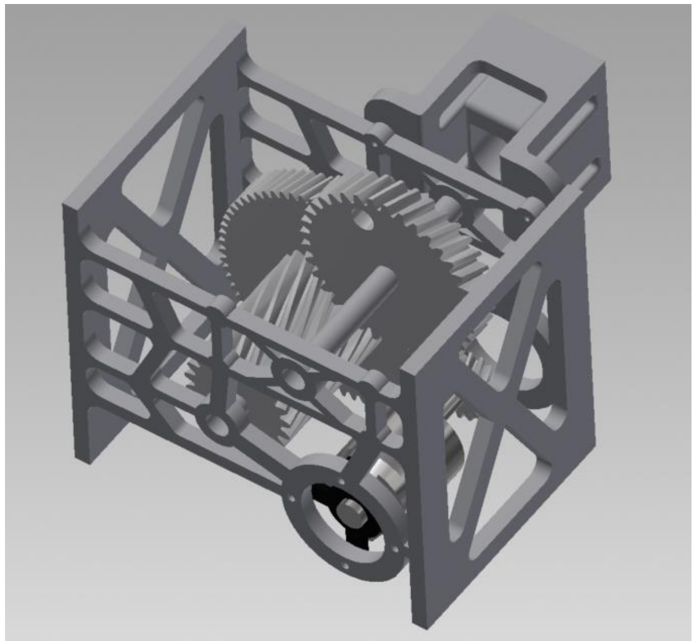

Figure 9: Final Preliminary Gearbox CAD

VI. Planetary Gearbox Design

The planetary gearbox design saves a significant amount of space, allows for better meshing of gears, and can perform at greater speeds than a conventional gearbox. Since the new gear ratio is 5,779:1, as shown below, this gearbox type is the optimal choice. In the end, the stages will decrease in ratio since, as a rule of thumb, having a higher ratio towards the drive gear is desirable but a ratio of greater than 10:1 can cause problems, the ratios are 10:1, then 10:1, then 8:1, then 7:1. These ratios multiplied together, since the stages are in series equate to a gear ratio close to 5,779:1.

Minimum ratio from torque calculations: 5:1

Approximate output ω requirement from average flow control: 67.2 deg of movement in 2.0 seconds

67.2deg/2sec*60sec/1min*1rev/360deg = 5.6 rpm “desired”

A current of 16 A has rpm set at 32,365 rpm, from the motor curves.

32,365/5.6 = 5779:1

10:1*10:1*8:1*7:1 = 5600:1 approximately 5779:1

There are four componants to each set of planetary gears. They are the Sun Gear (S), the Planet Gears(P), the Ring Gear(R) and the Planet Carrier.

Ratio=Driven/Drive=S/(R+S) = ringDia/PlanetDia*SunDia

Design of planetary gearbox will have all ring gears at roughly 3 inch diameters for construction and sizing restrictions.

Set 1 Ratio = 10:1

Next step is determining the size of the planetary gear and sun gear for each step. This is done with two equations and using a matrix to solve for the unknown diameters to achieve a ratio of 10:1 and can be seen below.

ringDia/PlanetDia*SunDia=10

3/PlanDia*SunDia=10

<u>.3SunDia-PlanDia=0</u>

Also known from the geometry of the planet and sun gear that 2 planet gear diameters plus 1 sun gear diameter fill a ring gear which is 3 inches.

<u>2*PlanDia+SunDia=3</u>

Using linear algebra with the two underlined equations, the planet gear must be 9/16" and the sun gear must be 15/8". This process is done for the rest of the sets 2-4.

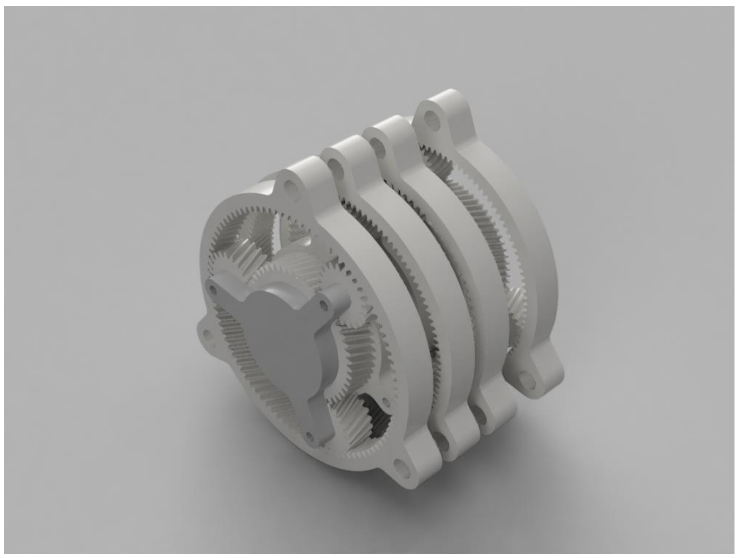

Figure 10: Final Planetary Gearbox CAD