Individual Design Project

The Mechanical Egg Beater

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Design Description

This mechanical eggbeater features carbon steel, aluminum alloy, and steel alloy parts. Its main feature is that it converts linear motion into rotational motion via a piston. This creative characteristic of the eggbeater is what separates it from other eggbeaters, and it justifies the number of parts used. The piston is attached to a gear that is attached to another gear which rotates the shaft when the handle is moved. This is opposed to rotating a handle to produce torque among the gear train. With this set-up, the maximum power that the system can produce via the whisk is 52 Watts with the assumption that the max oscillatory force that will be applied to the handle is approximately 20N which is consistent with the average person. The overall length of the eggbeater is 8 inches with a 4-inch shaft to ensure that you can mix from a safe distance away. The whisking part is comprised of 3 different carbon steel tubes and is approximately 4 inches tall. The housing and handle mechanism are designed to be held comfortably for a long time and the housing itself is 4”x2”x1.5” which makes it the perfect size for using it and for storing it.

There are 2 different sub-assemblies that make up this eggbeater. The first one is the reciprocating assembly which includes: the gear box, reciprocating house, handle, gear arm, a hex screw, and a hex nut. The reciprocating house is the main body of the entire eggbeater system and is what holds the gear system and the gear box. The gear box is inside the body of the reciprocating house and is fastened to the handle via a hex screw. The gear arm is then connected to the bottom part of the gear box, and this is the part that will attach to the second sub-assembly. The reciprocating house material is 1060 Aluminum alloy to reduce the mass of the system but still have a tough material. The gear box is carbon steel to increase the toughness, durability, and the yield stress so the repetitive use of the mechanism doesn’t cause failure. The handle is 1060 Aluminum alloy to reduce the total mass of the system because it would be inconvenient to be pulling and pushing a heavy handle. The hex screw and hex nut are both made of zinc-plated grade 5 steel to ensure the fasteners don’t fail.

The second sub-assembly is the gear train and shaft system. The components that make up this assembly are as follows: bevel gear, pinion, threaded rotary shaft, panel nut, ball bearing, socket screw, socket nut, whisk, and hex screws. The gear train is made up of the bevel gear and the pinion which both reside in the reciprocating house. The pinion is fastened to the threaded shaft which is also fastened to the whisk which is what ensures the transfer of torque. The shaft is connected to the reciprocating house via a panel nut and a ball bearing. The ball bearing is what allows the shaft to rotate with the pinion. The socket nut is attached to the fastener inside of the bevel gear to ensure that it won't fall and to allow for rotations to occur. The material of the bevel gear and the pinion are both carbon steel to ensure durability. The material of all the hex screws are zinc-plated grade 5 steel. The threaded rotary shaft is carbon steel to increase its yield strength to ensure that it won't fail due to the constant stresses it will be subjected to. The whisk will be made of stainless steel to have a high yield stress and to not rust due to it being in contact with foods. The socket screw material is black-oxide steel alloy to ensure that it wont rust and to reduce the possibility of it becoming unfastened due to the vibrations of the machine. The socket nut is a steel alloy. The ball bearing is stainless steel so it can have a high specific heat due to the constant friction it will experience. The panel hex nut is steel alloy to ensure high strength. This assembly is fastened to the reciprocating sub-assembly via the gear arm being fastened to the face of the bevel gear. Once this connection is made, any linear motion of the gear box will result in the rotation of the bevel gear which will transfer torque and power to the pinion and whisk via the shaft.

There is only one whisk connected to a rotating shaft and this is to reduce the total number of parts in the system. The power our whisk can generate is sufficient to stir ingredients and common mixtures and adding another pinion with a shaft to our system would make the system heavy and impractical to use. The total mass of the system is approximately 5lbs due to the quality of the materials chosen and the power one can produce with this system. Some of the constraints of this system is its mass. This system weights about 5lbs which is a little heavier than the industry standard making it difficult to hold for extended periods of time for some users. Some of the power constraints of this system are the gear ratios and the number of pinions. If the gear ratio was greater between the bevel gear and the pinion it would produce more torque at the whisk. Additionally, if there was another pinion attached to the bevel gear there would be the same amount of power produced, but it would be split among the two whisks which would allow for the more efficient transfer of power. Some of the materials constraints include the fact that to ensure durability of the system, it needs to be comprised of stronger materials which are typically denser. The shaft can also be detached to clean it easier or to install another one.

Isometric Image of Design

Exploded Isometric Image of Design

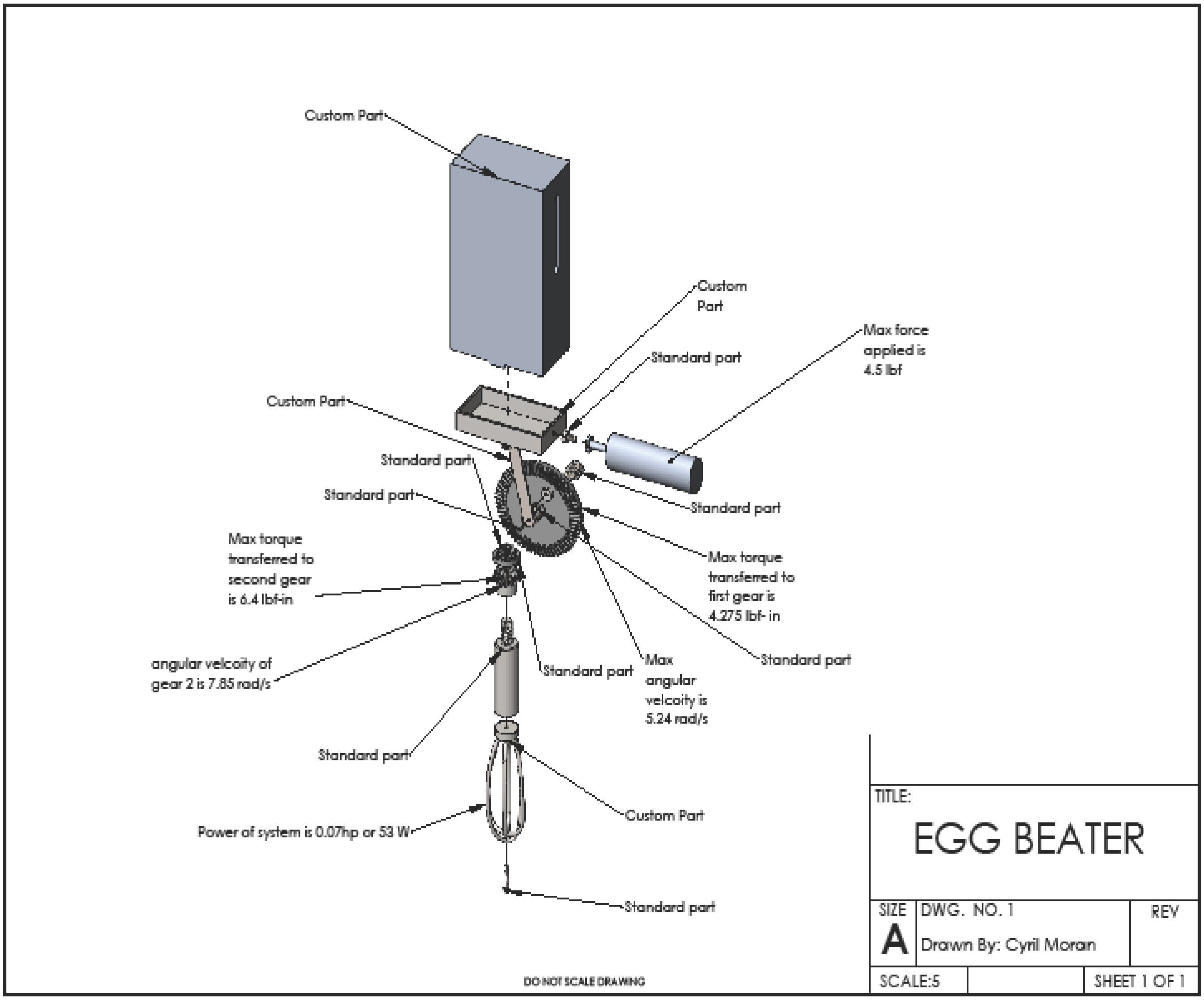

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Table 1: Parts List

Part Name	**Quantity**	**Description**	**Material**	**Standard Part (Y/N)**
Bevel Gear	1	Gear pitch of 16, pressure angle of 20°, face width of 0.48”, and 24 teeth.	1144 Carbon Steel	No
Pinion	1	Gear pitch of 16, pressure angle of 20°, face width of 0.48”, and 16 teeth.	1144 Carbon Steel	Yes
Socket Nut	1	Length of 0.62” with a thread type of $\frac{3}{8}$"-24.	Alloy Steel	Yes
Threaded Rotary Shaft	1	Length of 3.0”, thread type of 6-32, and an outer diameter of 0.5”.	Carbon Steel	No
Handle	1	Length of 4.0”, and a diameter of 1.6”.	1060 Aluminum Alloy	No
Gear Housing	1	Length of 8.2”, width of 2.5”, a height of 4.35”, and a shell of 1.5”.	1060 Aluminum Alloy	No
Gear Box	1	Length of 4.05”, and a height of 2.2”.	Carbon Steel	No
Gear Arm	1	Length of 3.35”, and a thickness of 0.05”.	Carbon Steel	No
Whisk	1	Carbon steel wires that are approximately 2.5 inches in length.	Stainless Steel	No
4-40 Hex Screw	1	Length of $\frac{3}{8}$" and is fully threaded.	Zinc-Plated Grade 5 Steel	Yes
$\frac{1}{4}$-20 Hex Screw	2	Length of $\frac{3}{8}$" and is fully threaded.	Zinc-Plated Grade 5 Steel	Yes
$\frac{5}{16}$-18 Hex Screw	1	Length of $\frac{1}{2}$" and is fully threaded.	Zinc-Plated Grade 5 Steel	Yes
18-8 Hex Screw	1	Length of $\frac{1}{2}$" and is partially threaded.	Stainless Steel	Yes
6-40 Socket Head Screw	1	Length of 1.0" and is fully threaded.	Black-Oxide Alloy Steel	Yes
Ball Bearing	1	Inner diameter of $\frac{1}{2}$"and an outer diameter of 0.625”	Alloy Steel	Yes
½ Hex Panel nut	1	Inner diameter of $\frac{1}{2}$"and a height of $\frac{1}{10}$".	Alloy Steel	Yes
Total Number of Parts:	17			

Design Calculations

Gear Ratios:

$$Ratio = \frac{\#\ of\ teeth\ Gear1}{\#\ of\ teeth\ Gear\ 2}$$

$$Ratio = \frac{24}{16}$$

$$Ratio = 1.5$$

Angular velocity of Gear 1:

$$RPM_1 = 50$$

$$\omega_1 = 50\frac{rev}{min}\cdot\frac{2\pi}{rev}\cdot\frac{1min}{60s}$$

$$\omega_1 = 5.24\frac{rad}{s}$$

Angular Velocity of Gear 2:

$$RPM_2 = RPM_1 \cdot Ratio$$

$$RPM_2 = (50\frac{rev}{min}) \cdot 1.5$$

$$RPM_2 = 75\ \frac{rev}{min}$$

$$\omega_2 = 75\ \frac{rev}{min}\cdot\frac{2\pi}{rev}\cdot\frac{1min}{60s}$$

$$\omega_2 = 7.85\frac{rad}{s}$$

Max Torque on Gear 1(where d is the distance from the center of the gear to the gear arm pin):

$$T_{\max} = F_{applied} \cdot d$$

$$T_{max} = 4.5\ lbf \cdot 0.95in$$

$$T_{max} = 4.275\ lbf \cdot in$$

Torque transfer to Gear 2:

$$T_t = T_{max} \cdot Ratio$$

$$T_t = (4.275\ lbf \cdot in) \cdot 1.5$$

$$T_t = 6.4\ lbf \cdot in$$

Max Power:

$$P_T = T_t \cdot \omega_2$$

$$P_T = (6.4\ lbf \cdot in) \cdot (7.85 \frac{1}{s})$$

$$P_T = 50.34 \frac{lbf \cdot in}{s}$$

$$P_T = 0.07hp \approx 53\ W$$

Position of Box Relative to Gear 1:

$$l^2 = r^2 + x^2 - 2 \cdot r \cdot x \cdot \cos(\theta)$$

Where *l* is the length of the box to the crank pin on the gear, *r* is the distance from the center of the gear to the crank pin, *x* is the distance of the box from the gear center, and θ is the angle between *x* and *r*.

$$l^2 - r^2 = (x - r \cdot \cos(\theta))^2 - r^2 \cdot \cos(\theta)$$

$$l^2 - r^2 + r^2 \cdot \cos^2(\theta) = (x - r \cdot \cos(\theta))^2$$

$$l^2 - r^2 \cdot (1 - \cos^2(\theta)) = (x - r \cdot \cos(\theta))^2$$

$$l^2 - r^2 \cdot \sin^2(\theta) = (x - r \cdot \cos(\theta))^2$$

$$x = r \cdot \cos(\theta) + \sqrt{l^2 - r^2 \cdot \sin^2(\theta)}$$

Velocity of Box Relative to Gear 1:

$$x' = \frac{dx}{dA}$$

$$x' = -r \cdot \sin(\theta) + \frac{\frac{1}{2} \cdot -2 \cdot r^2 \cdot \sin(theta) \cdot \cos(\theta)}{\sqrt{l^2 - r^2 \cdot \sin^2(\theta)}}$$

$$x' = -r \cdot \sin(\theta) - \frac{r^2 \cdot \sin(\theta) \cdot \cos(\theta)}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}}$$

Acceleration of Box Relative to Gear 1:

$$x'' = \frac{d^2x}{dA^2}$$

$$x'' = -r \cdot \cos(\theta) - \frac{r^2 \cdot cos(\theta)}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}} - \frac{-r^2 \cdot \sin^2(\theta)}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}} - \frac{r^2 \cdot (cos(\theta) \cdot \sin(\theta))^2 \cdot r^2}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}^3}$$

$$x'' = -r \cdot \cos(\theta) - \frac{r^2 \cdot (\cos^2(\theta) - \sin^2(\theta))}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}} - \frac{r^4 \cdot (cos(\theta) \cdot \sin(\theta))^2}{\sqrt{l^2 - r^2 \cdot \sin(\theta)}^3}$$