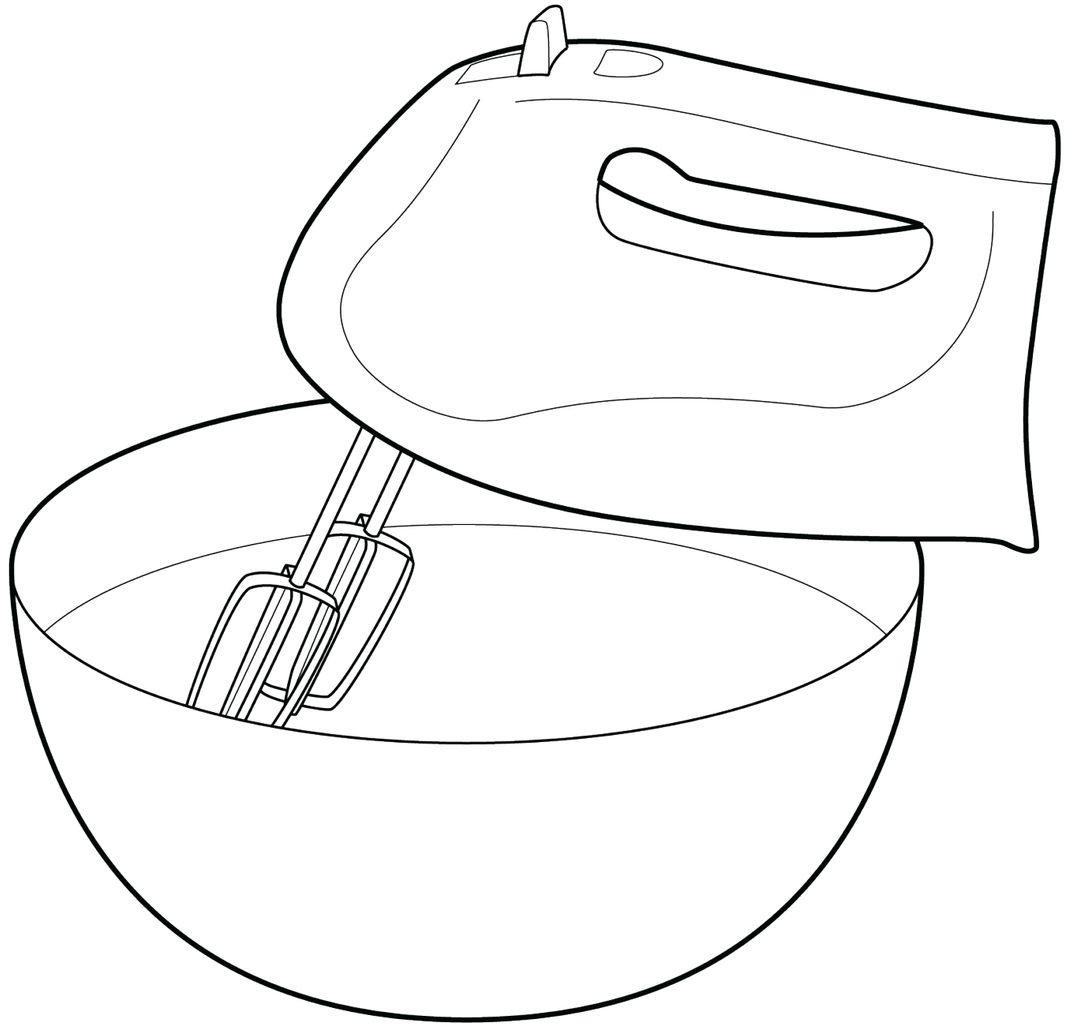


Hamilton Beach Hand Mixer

Emily Spooner, Franklin Guttman, Janet Peng, Wenqing Yin

How Things Work | Fall 2019

Context

Intended Use

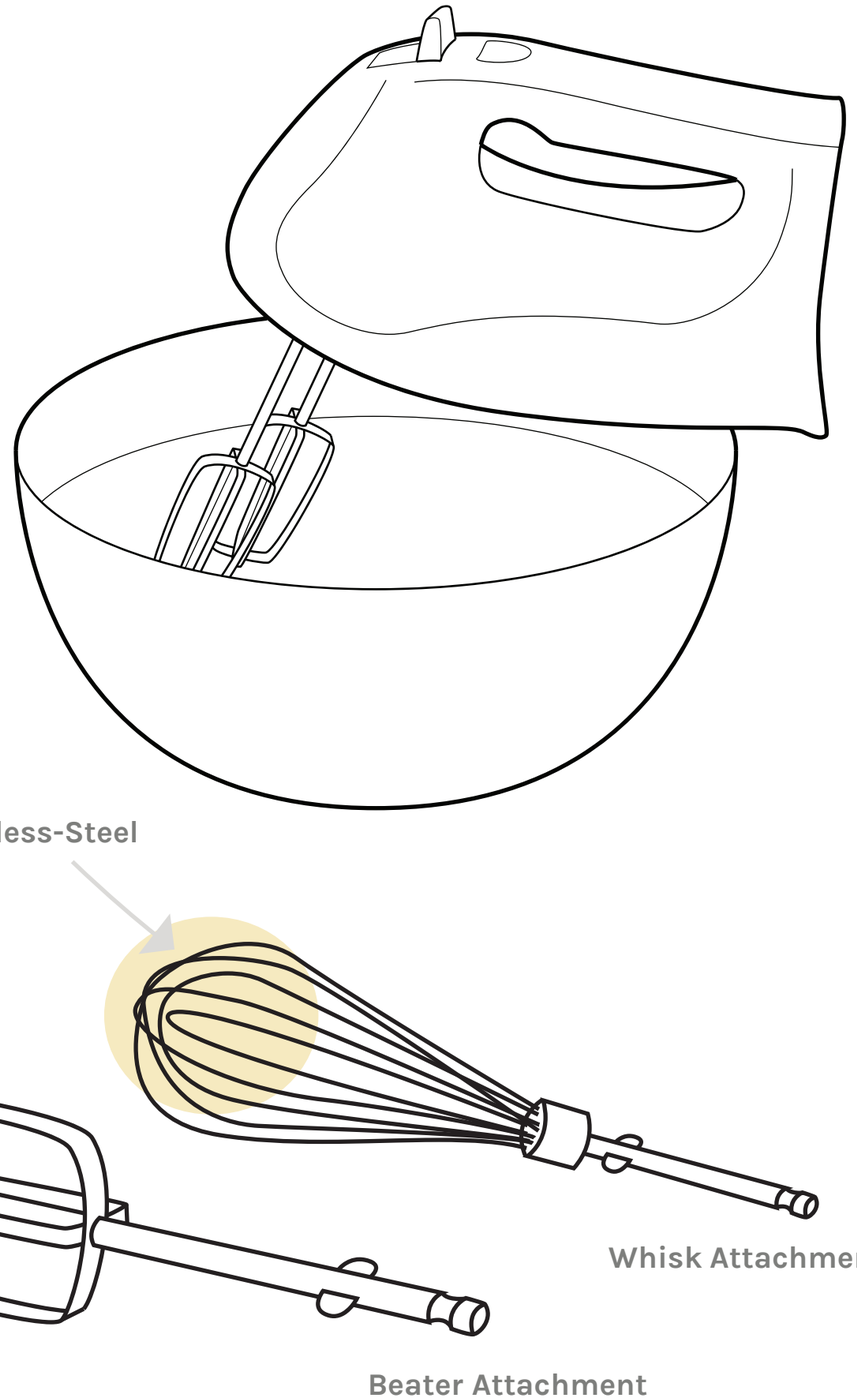
Hand mixers are primarily an alternative option to standing mixers, with easier usage for whisking rather than beating. However, it can still handle heavier loads using beater attachments, such as for cookie dough or batter. Additionally, the compact housing design of hand mixers allows them to be used at quick notice, as opposed to standing mixers. Whereas other heavy duty appliances are used in kitchens that cook often, the convenience and ease of use of a hand mixer means its used even in kitchens with infrequent cooking.

Materiality

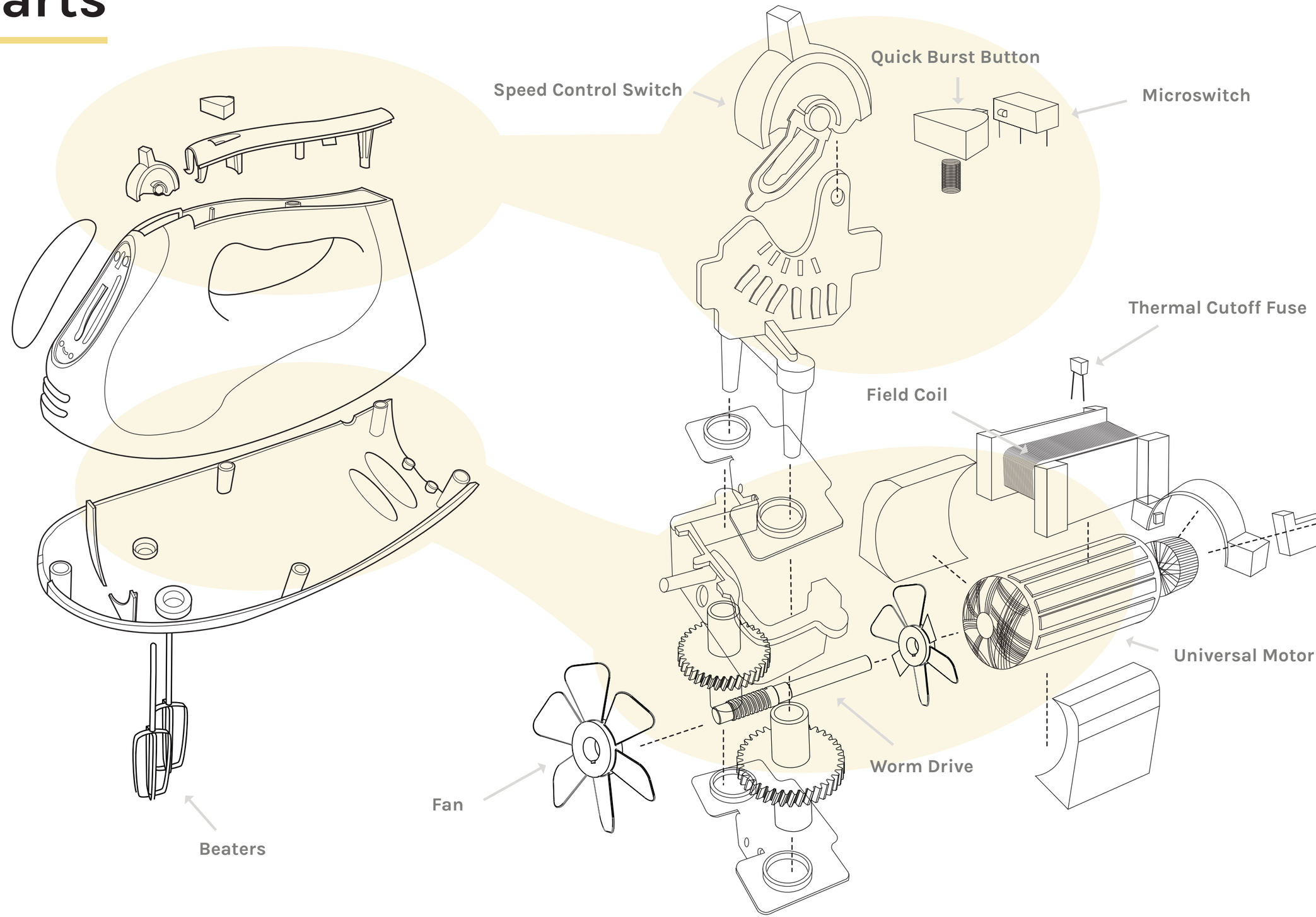
The beater attachments are chrome-plated, as are other attachments such as dough hooks and milkshake mixer. Chrome-plating is used for improved wear and corrosion resistance. The hardness and durability of the chromium metal surface finish means the attachments will last longer even under severe mechanical contact and wear. Additionally, damaged chrome-plated parts may be refurbished, saving the expense of having to purchase new parts if desired.

Whisks are stainless steel, except for the shaft which is also chrome-plated. Stainless steel is used due to its ability to withstand extreme weather and temperatures and it will not corrode or oxidize. This durability is especially important due to the thinness of the whisk.

The major advantages include its high corrosion resistance allowing it to be used in rigorous environments. It is resistant to heat allowing it to resist scaling and retain strength at high temperatures.



Parts


Speed Control Switch
Quick Burst Button
Microswitch
Thermal Cutoff Fuse
Field Coil
Universal Motor
Worm Drive
Fan
Beaters

Ergonomics

Many ergonomic considerations were taken into account when designing the form of the hand mixer. These properties of the product help make the use of it more efficient and comfortable for the user.

Material

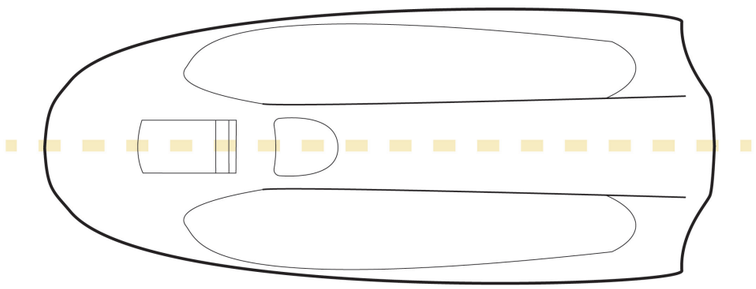
The outer casing of the mixer is made out of plastic. This material adds little weight to the product so that it is easier to lift and manipulate while mixing.

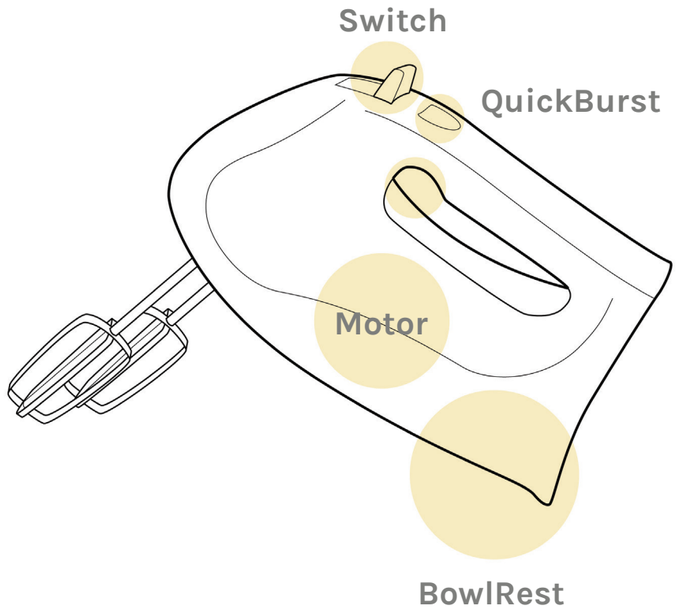
Weight Distribution

The heaviest part inside the hand mixer is the motor as it is mainly constructed of metal for conductive purposes. The motor sits in the middle of the mixer so that neither the front or back is too heavy. This even weight distribution makes the product easier to hold and control.

Symmetry

The mixer is symmetrical. This makes the experience of using the product with your left hand the same as using the product with your right hand.



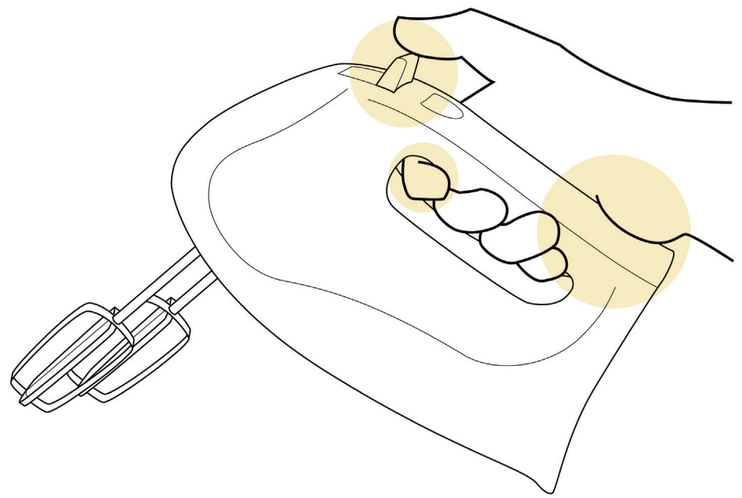


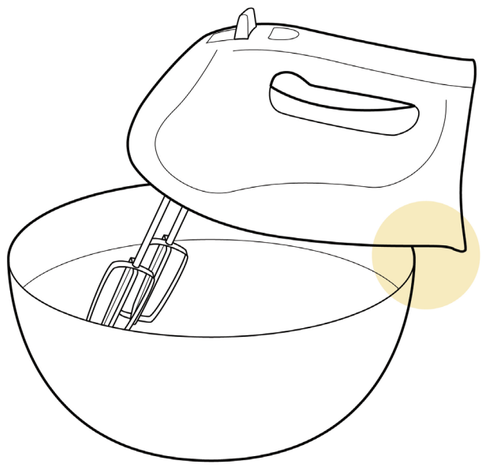
Handle

The handle is shaped with a curve for the index finder. This grip provides the user with more control of the product while in use. The curved top of the handle makes the product more comfortable to hold as its shape matches the curve of the thumb. The grip structure of the handle causes the thumb to hover over where the switch and QuickBurst button are. This allows for easy access to speed change, beater attachment ejection, and the QuickBurst.

BowlRest

The back of the mixer is curved and has two grooves. This is so that the mixer can sit on the bowl when it not in use. The user can also rest part of the weight on the bowl when they are using the hand mixer. The groove closer to the back accommodates larger bowls and the front groove is for smaller bowls.

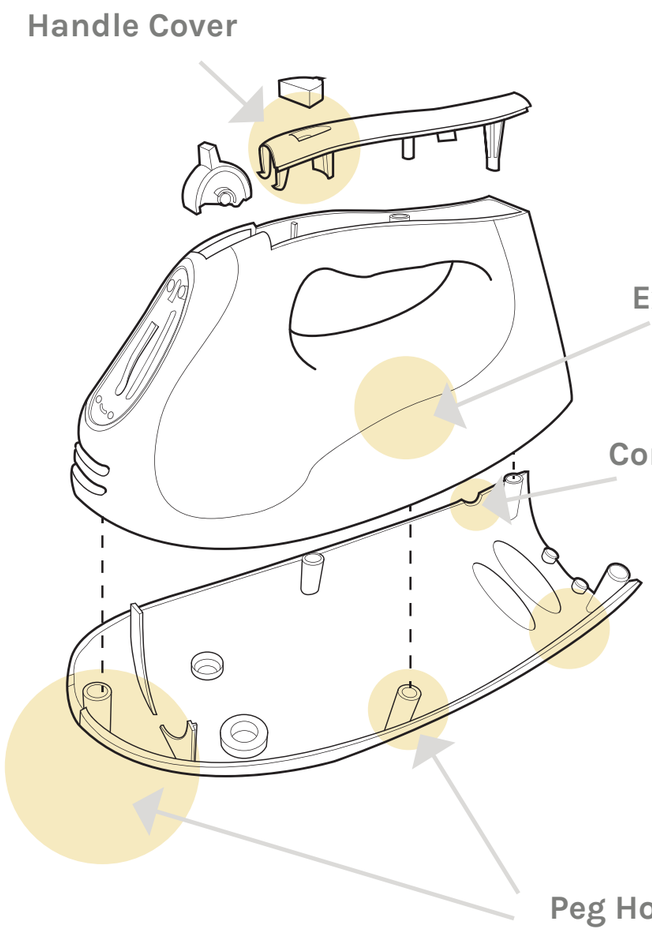


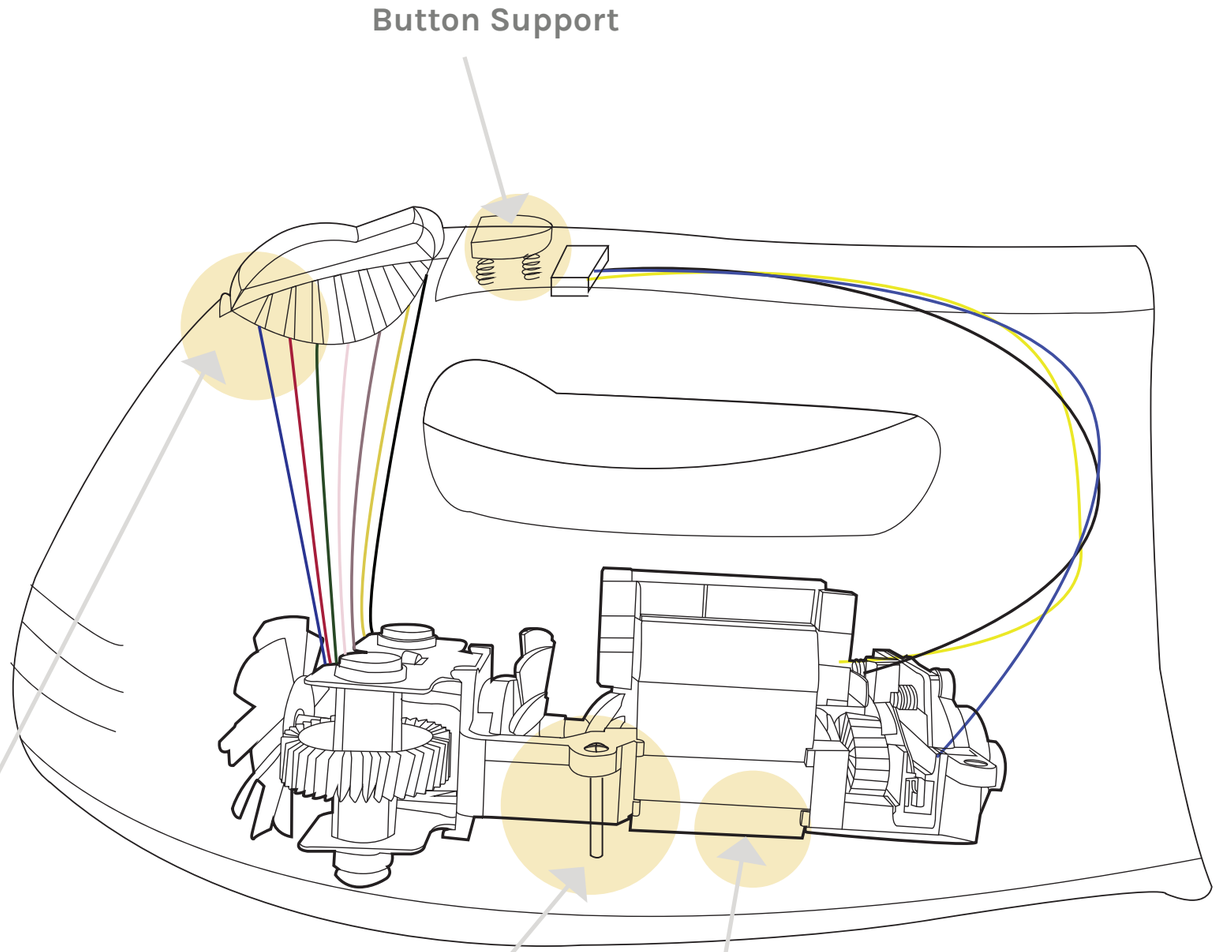


Housing

Wiring Pattern

The wiring within the hand mixer revolves around the placement of the motor in the bottom half of the housing and is reflected by the exterior curve of the plastic shell. The motor's carefully structured fit within the motor (surrounded by plastic pegs) is required due to the high stability needed to handle the strong torque of the motor. The other key fragile elements, the QuickBurst and microswitch, are held in place by the handle cover at the top of the mixer.

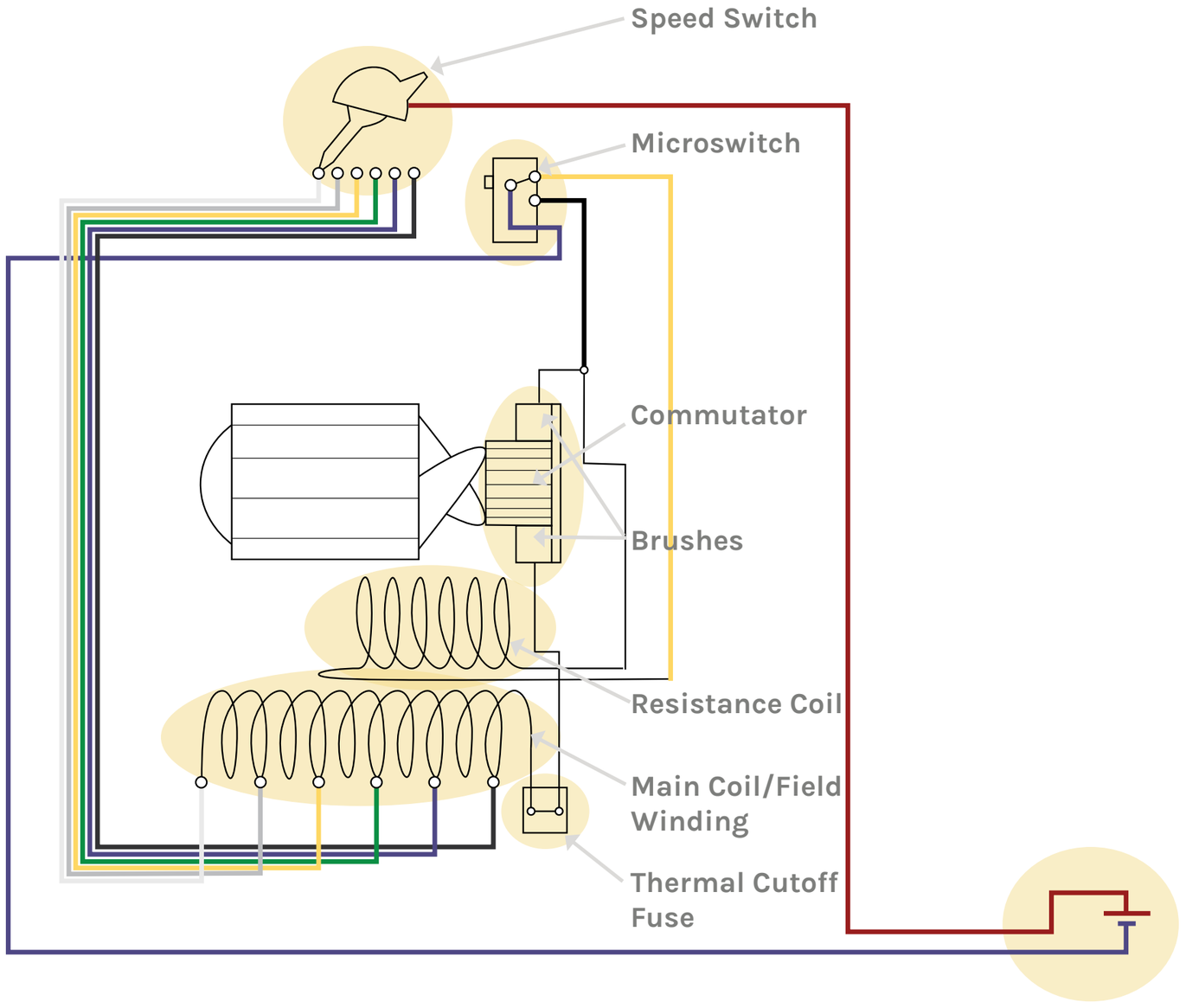




Wiring Diagram

Overview

Current from the wall passes through the red internal wire before continuing through to one of six speed wires (or off, connected to nothing), chosen by the switch. Current then flows through the copper coil, creating a magnetic field. After the thermal cutoff fuse, the current then continues to the brushes which sends current to the commutator of the motor which, combined with the magnetic field from the coil, causes the motor to rotate. After passing through the commutator and the brush on the other side, the current passes through either a yellow wire or a black wire, depending on whether the QuickBurst button is pressed. The yellow wire is connected to an additional resistance coil before reaching the microswitch, while the black wire is directly connected to the microswitch, avoiding additional resistance. No matter which wire the current passes through, it ends up connected to the blue wire, finally leading the current out of the system.



Speed Control Switch

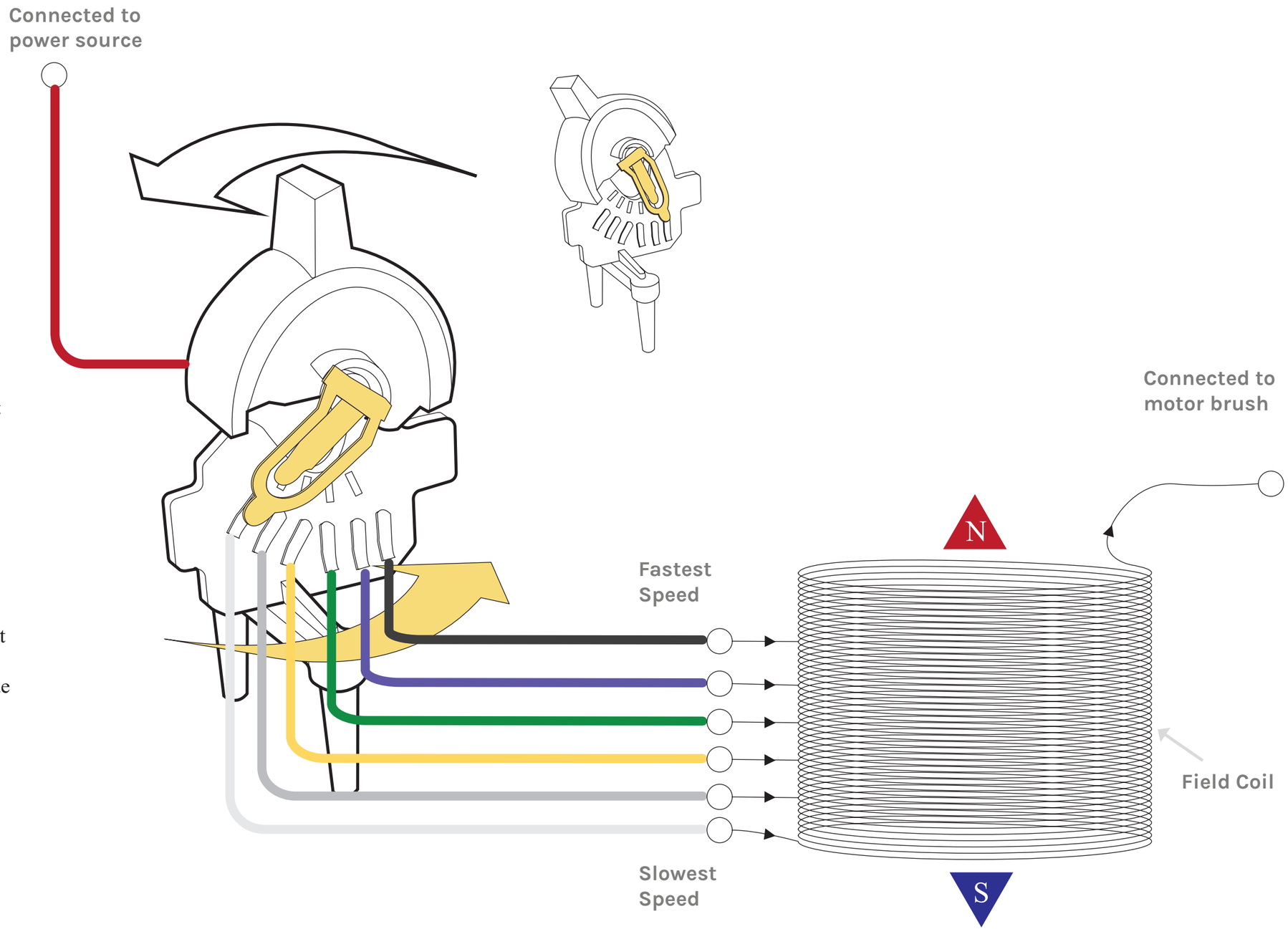
Overview

The speed control switch has seven states including the off state and six speed settings. Rotating the plastic part of the switch causes the metal conductor to touch either one of the six wires which are further connected to a different number of coils respectively.

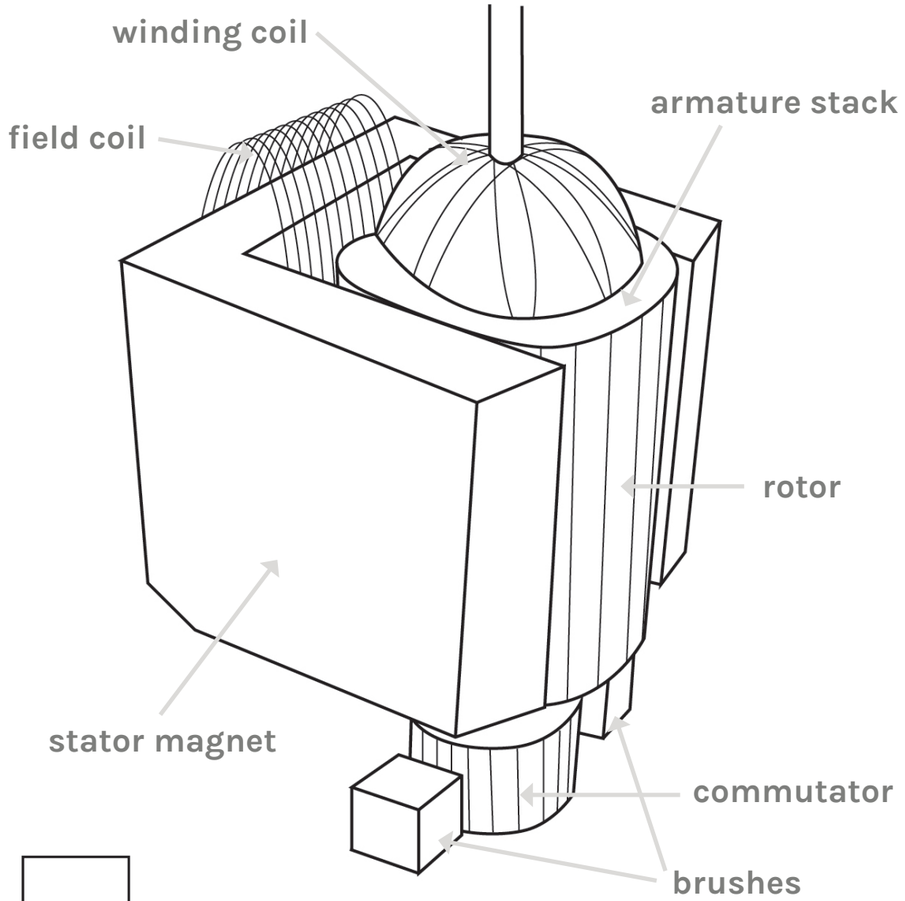
Physics Principles

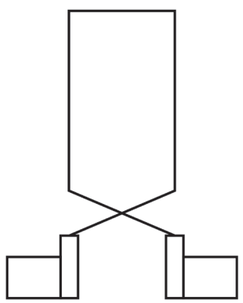
The switch is connected to the field coil. Field coils are wrapped copper wires that are under the motor. Based on the right-hand rule, the coil generates magnetic field when it is charged to provide rotational force for the motor.

A larger number of coils will result in more resistance. The increase in resistance causes the current in the circuit to decrease, which further reduces the speed of the motor. Therefore, when the switch is connected to the white wire, the motor will be in the lowest speed setting; while connected to the black wire, the motor will be in the fastest speed due to the least resistance.



Universal Motor

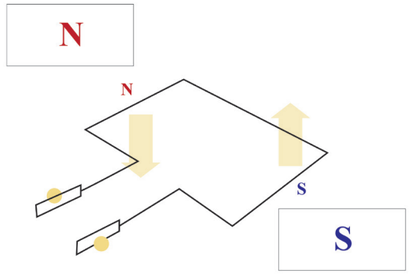




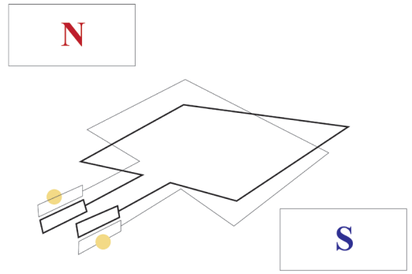
wiring diagram - active coil in the armature

Design considerations

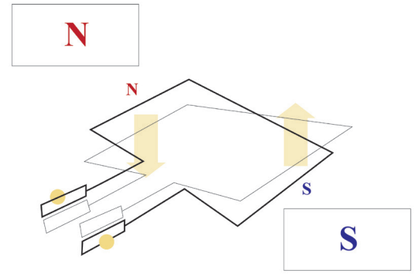
Some of the bars in the armature stack have slight indents in them. This causes the armature stack to be unevenly weighted, letting gravity help direct the armature in the desired rotation direction. All wires in the motor are insulated so that they don't share charge with neighboring wires.



current creates magnetic field that pushes the armature



when the armature rotates, the now active coil is disconnected



the next coil is connected and the same magnetic field appears again

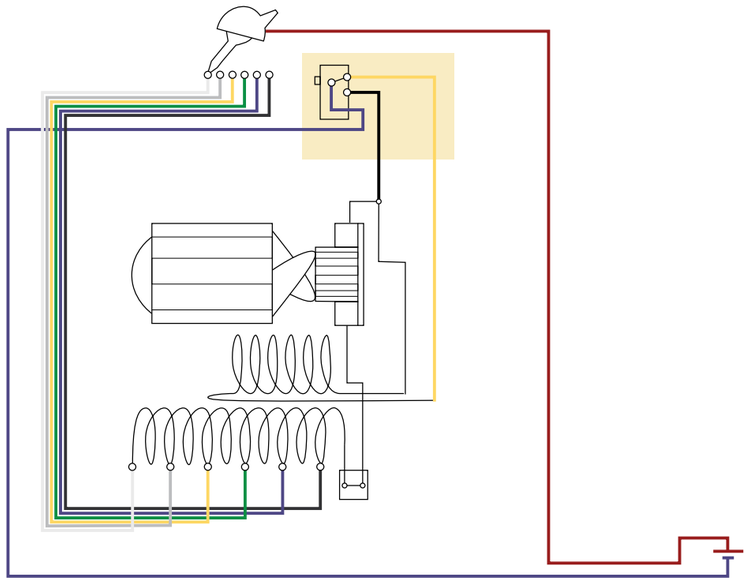
How it works

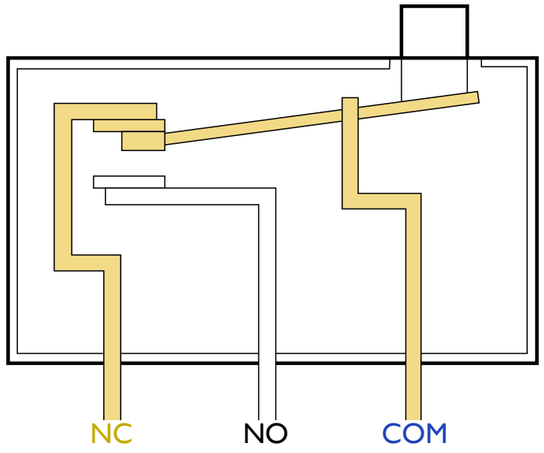
The universal motor consists of an outer electromagnet called the stator magnet and an inner electromagnet called the rotor. The magnetic field in the stator magnet is determined by the field coil. This magnetic field causes the rotor to rotate by constantly attracting and repelling the rotor. Since one side of the armature is positively changed (north) and the other side is negatively changed (south), one side of the armature is repelled from its current side and attracted to the other side.

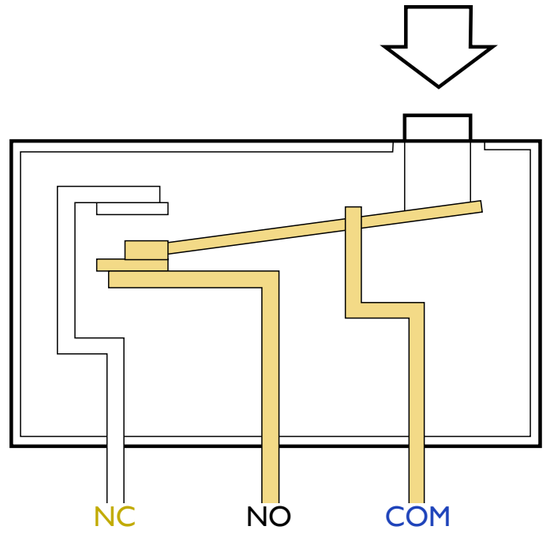
The stator magnet and rotor maintain almost continuous matching magnetic fields by having many commutator bars, each connecting to a different coil. Only the two commutator bars touching the brushes have current running through them. This causes only the coil connected to those bars to be magnetic. This means that only the armature stacks closest to the stator magnets are magnetized in a way that causes the armature to rotate. Once the armature starts to rotate, the current disconnects from the active coil and reconnects to the next commutator bars now touching the brushes, providing charge to next coil.

Power from the plug comes in as AC current, meaning that the current direction constantly changes. Because the field coil and rotor are getting their power from the same source and are connected in series, the change in current (and thus, the magnetic field) happen at exactly the same time. This maintains the attractions and repulsion causing the rotor to continue to rotate in the same direction. In fact, because the rotor and stator magnets are connected in series, either an AC or DC power source will work with this motor. This is why it's called a universal motor.

QuickBurst Function







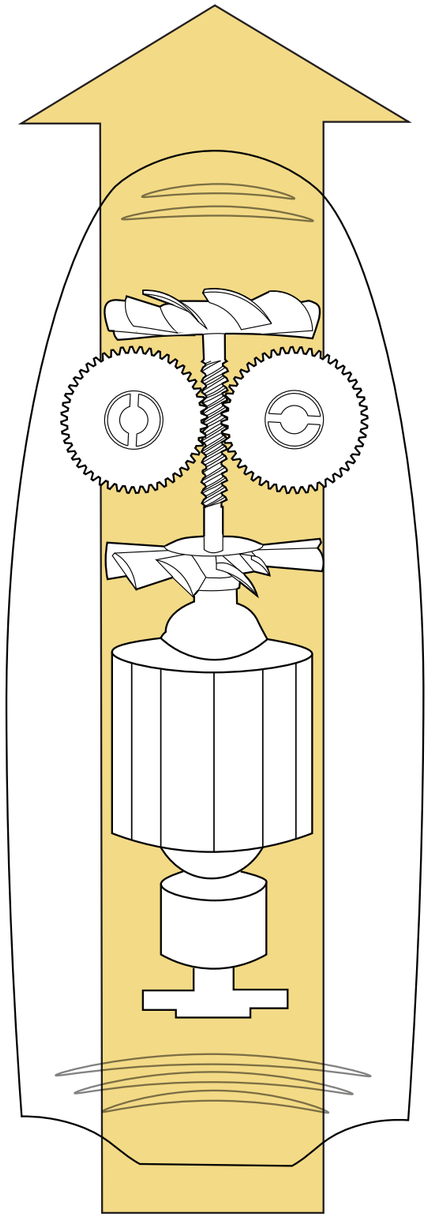
Summary

The QuickBurst button on the hand mixer allows the user to temporarily increase the speed of beating while the button is pressed. This is done using the wiring that comes after the brushed motor, as it is split into two separate wiring paths. The yellow wire connects to a separate coil before going into the microswitch, a mechanism that requires very little force to enact. Since the resistance coil runs in the opposite direction, it adds additional resistance while also creating a magnetic field that runs opposite the main coil, increasing resistance. The black wire is directly connected to this microswitch, meaning that it requires much less resistance compared to the yellow wire. The blue wire is the common wire that, depending on the state of the switch, either the yellow or black wire connects to and current flows out of the mixer system.

Wiring

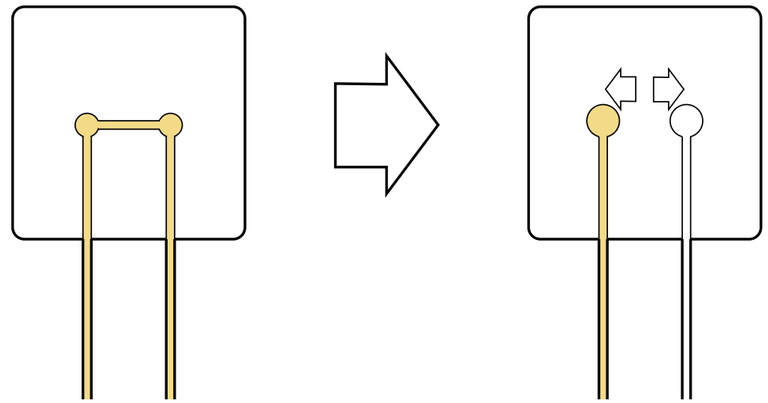
The blue wire is designated with the abbreviation COM for Common, since it is used in both states of the switch. The yellow wire, from the path with the greater resistance, is designated as NC or Normally Closed, since it is the mixer's default setting without the button pressed. The black wire, on the other hand, is NO or Normally Open, since without the button being pressed it has nothing to connect itself to. When the button is pressed, however, the overall system has much less resistance than normal by bypassing the resistance coil, resulting in the "burst" of increased current.

Temperature Safety



Airflow Control

Two fans are put in place to regulate air flow in and out of the mixer. Vents on the front and the back of the housing shell bring in cool outside air and push out warmer air from inside the mixer as the parts generate heat. Note that the central fan has two notches removed from the blades, one on each side. This is to reduce suction caused by the overlapping of the fan blades, which conserves velocity and creates a quieter sound.

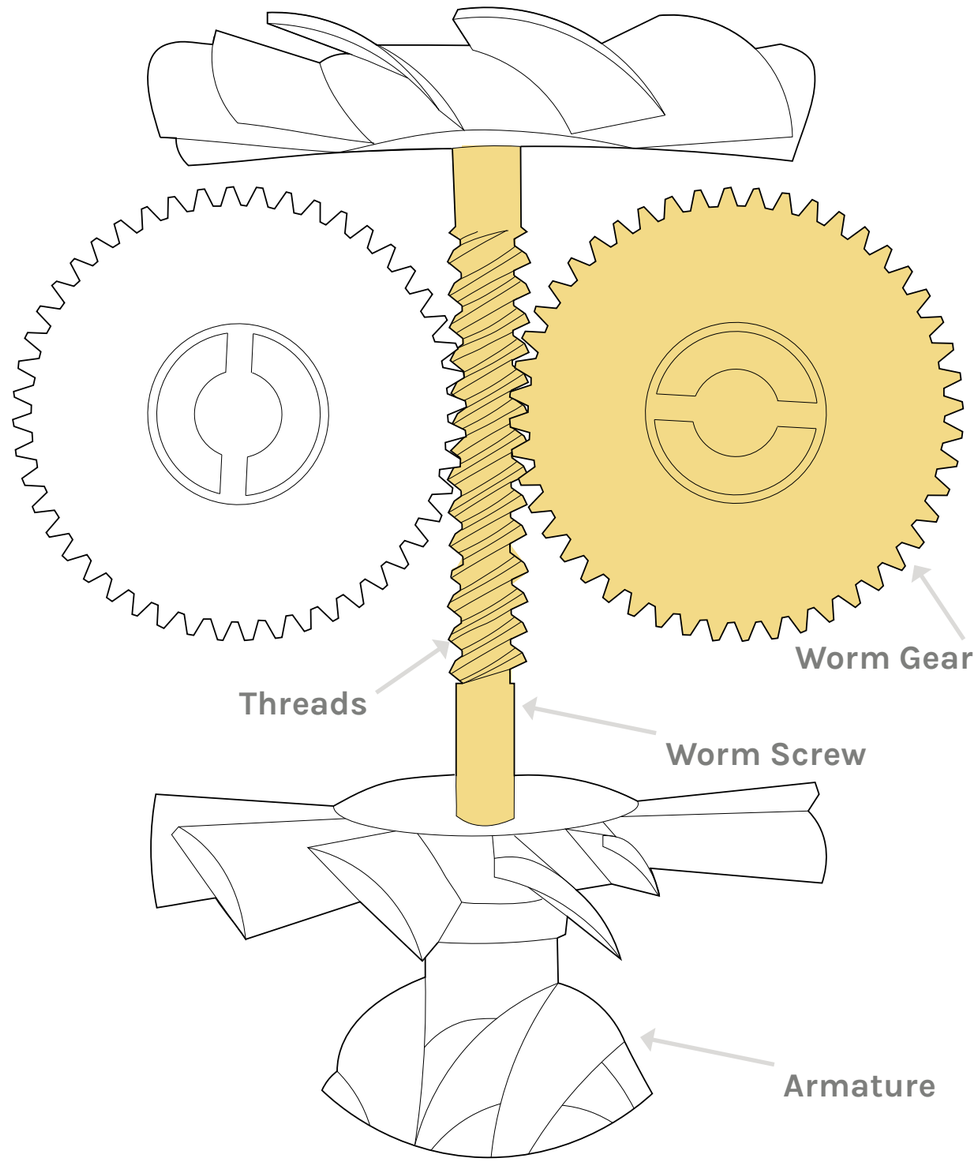


Thermal Cutoff Fuse

In the case that the mixer does overheat, the electronics system has a radial lead thermal cutoff switch pressed against the copper coils that will instantly break the circuit and cut the power to prevent the risk of user injury. The thermal rating of the device is inscribed on the back, meaning it will break when the internal temperature of the machine exceeds that number. This is because the alloy inside that connects the two wires melts at that temperature, causing the connecting wire to liquify and flow into the two radial balls at the sides of the wires due to surface tension. This type of thermal cutoff switch is non-resetting, meaning that once the device overheats, the circuit is permanently opened and cannot be closed again without replacing the thermal cutoff switch.

Beater Mechanism

Worm Drive

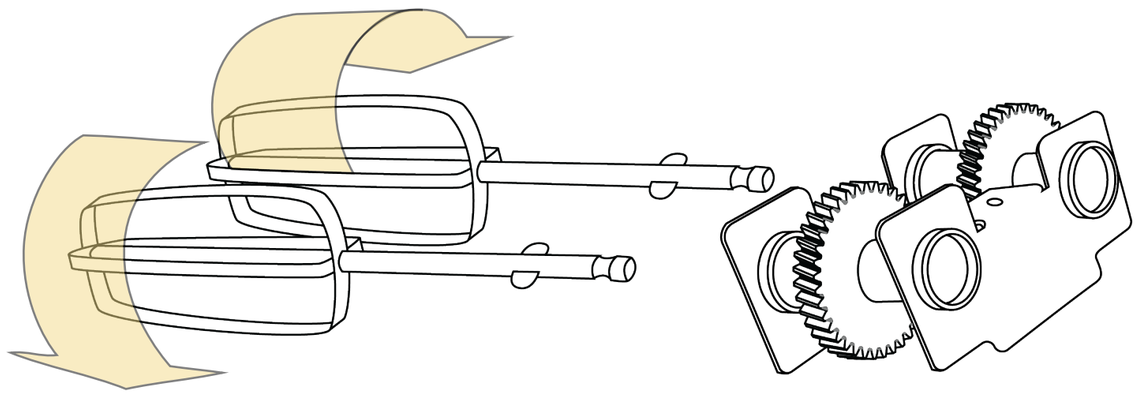


Function

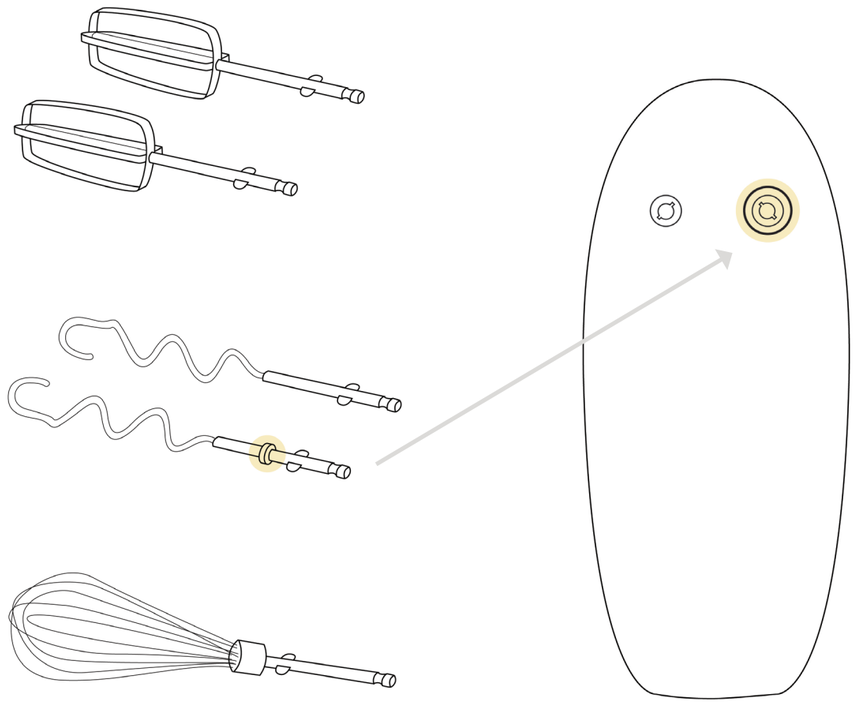
The beaters use the rotational motion from the universal motor in order to spin through a worm drive. Directly connected to the armature of the motor is the worm screw which is dual-threaded to turn the worm wheels on either side at a ratio of 21:1 (21 full rotations of the motor to one full rotation of the beaters). The purpose of the worm drive is to ensure that both beaters move at exactly the same rate to prevent them from colliding with each other. The opening for each beater is offset slightly from one another so that the spoke of one beater fits exactly into the opening of the other. Since each worm wheel resides on either side of the worm screw, the beaters themselves rotate in opposite directions, pushing the load between the beaters outward on either side equally.

Push Back

When the beaters are in use, the load that the hand mixer is trying to mix may resist the torque. This causes the load to “push back” on the attachments. To compensate for this force, there is a ball bearing at the end of the shaft furthest from the beaters. This ball bearing prevents the shaft from being sent back into the mixer if too much force is resisting the beater’s movement.



Beaters and Attachments



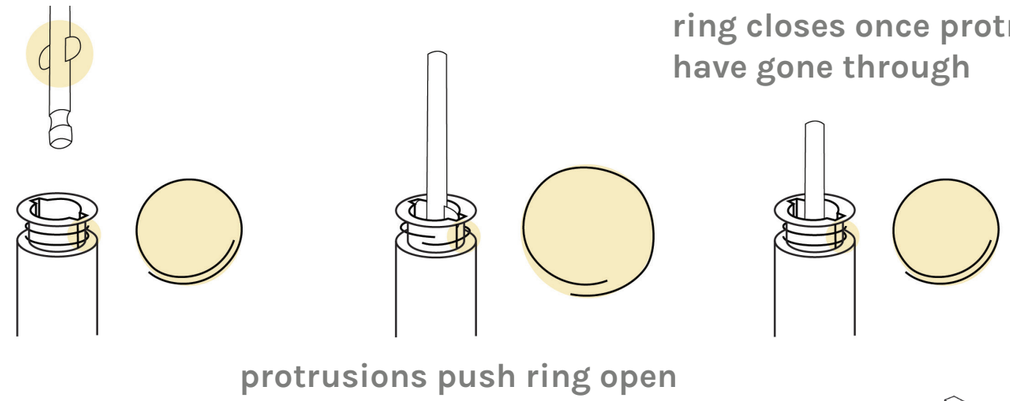
There are several different attachments that can be inserted into the hand mixer's body. Each serves a different purpose but they all insert into and remove/eject from the body in the same way.

Different Attachments

To attach a beater, insert the long end of the beater into one of the holes at the bottom of the mixer. For most beaters, their arrangement does not matter. However, when beaters do come in a left-right pair where one must be inserted on the left and the other on the right so that they do not hit each other while rotating, the left beater will have a ring. This is so that the left beater must enter the left hole as the rim on the left dips down to accommodate the protruding ring. Symmetrical beaters don't have a specified arrangement while irregular beaters (such as dough hooks) come in a left-right pair.

Inserting

When a beater is being inserted, the user will push the beater into the hole. This force will push the small protrusions/wings of the rod into a metal ring, causing the ring to open. When enough force is applied, the ring will open enough to let the rod go through. Once the protruding pieces are through, the ring will close back up since the ring is molded to return to its original position once the force is gone.

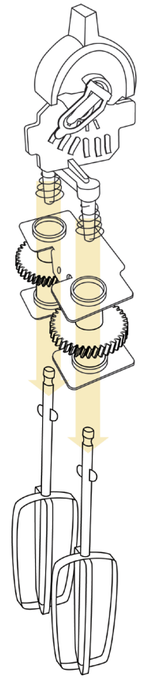


Removing

Similar to inserting, one method of removing a beater is by manually pulling it out. Like how the rod and protrusions interact with the metal ring while going in, when pulling the beater out, the ring opens when force is applied to the ring through the protrusions and closes once the force is gone.

Ejecting

When the beaters are dirty, it is inconvenient to pull on them to remove them from the body. The other way to remove the beaters is by pushing down on the switch. The switch connects to two plastic cone that pushes on the beaters from the top. This force interacts with the metal ring in the same way. Springs surround the plastic piece so that the switch pops back into place after being pushed down. A rectangular plastic piece at the bottom of the switch ensures that the switch is not pushed down too far.

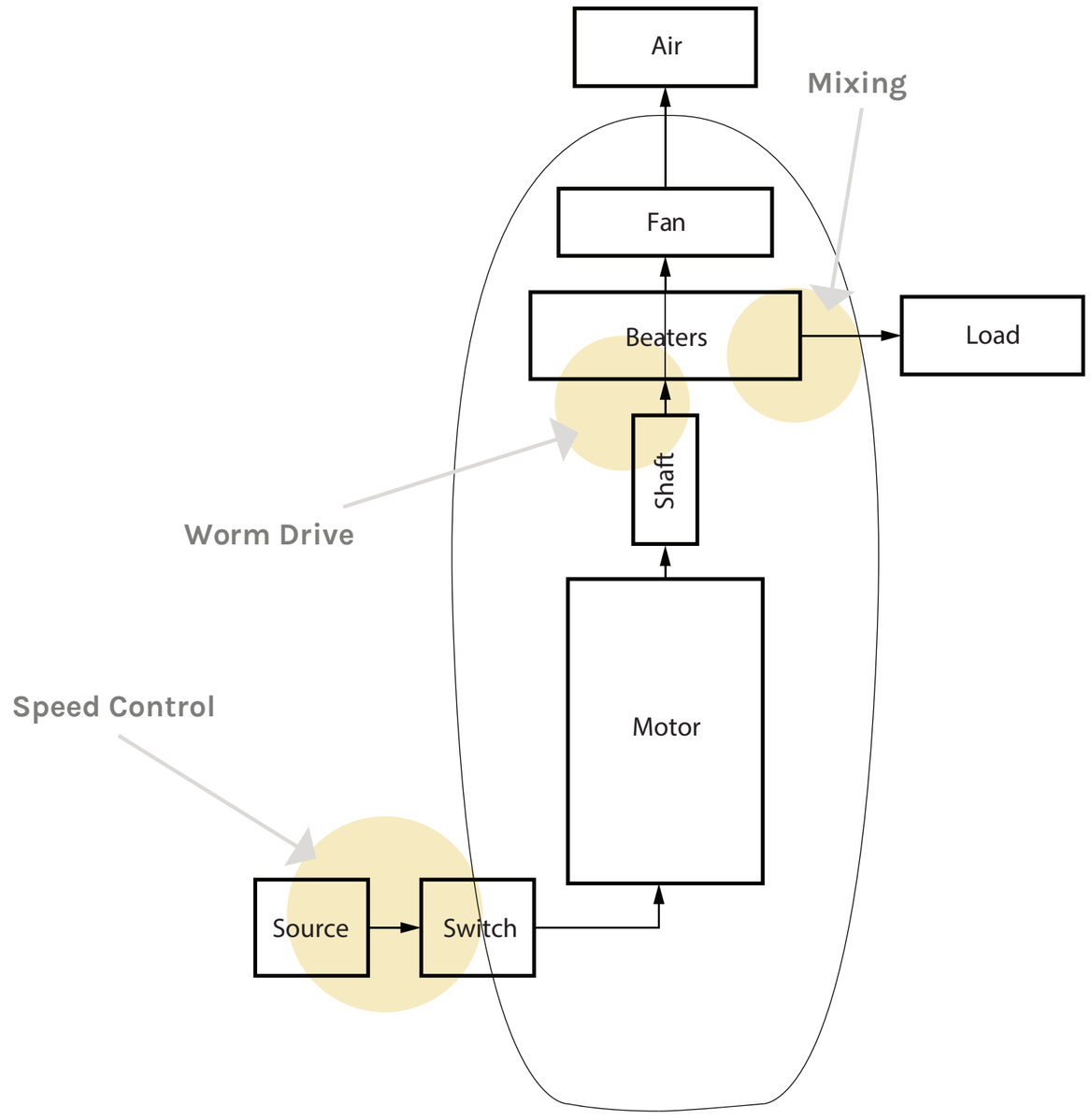


Block Diagram

Component Relationships

The hand mixer's motion is primarily driven by the relationship between its motor, the beaters, and its switch, a causality that enables it to shift large amounts of load at varying degrees of speed. As electrical power flows from the source (outlet) and into the motor, it is regulated by the switch, which determines both its on/off state and its the degree of resistance that the beaters' torque faces. From there, the motor's output moves the beaters in opposite directions through its connection by the shaft, and warm air is pushed out of the mixer by the fan.

Once this relationship is fully connected, it operates at different speed levels allowing it to manage various types of loads.



Conclusion

Ergonomics

Ergonomics are a main priority in the design of the housing: the curves of the handle allow the user to grip the machine with ease; the position of the switch and the QuickBurst buttons fit the thumb very well; the symmetry makes the mixer both right and left hand friendly; the BowlRest allows the user to rest the hand mixer on the bowl.

Other than human factors, the curves on the housing also matches the design of the internal structure of the hand mixer and hints at the direction of current flow.

Electromechanics

Apart from the external design, the design of the internal parts that are invisible to the users are also thoughtful and well-organized.

In the hand mixer, the universal motor is the core part that enables the beaters to rotate. Universal motors have the advantage of higher starting torque, quick starting and stopping, reversibility, and variable speeds.

Through adjusting the position of the switch and pressing the QuickBurst button, the user can activate twelve different mixing speeds, which is achieved by changing the motor's stator magnet's magnetic field.

Safety is also taken into consideration in the design of this product. The current will be cut off when the temperature exceeds the maximum and two fans help keep the system cool.